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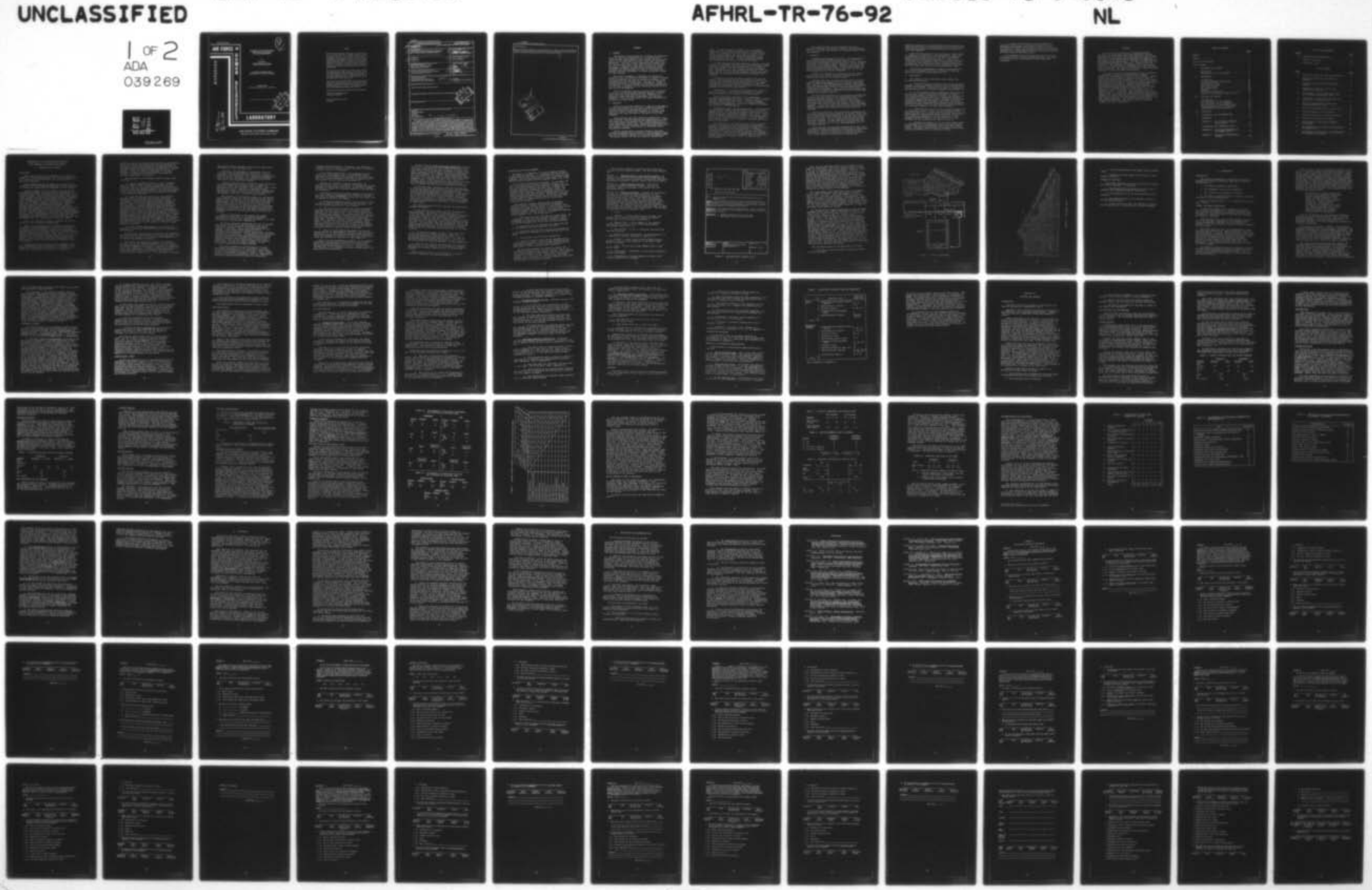

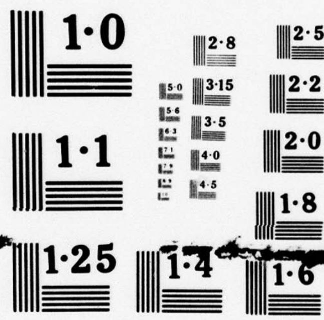

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ASSESSMENT OF A PROTOTYPE HUMAN RESOURCES DATA HANDBOOK FOR SYSTEMS ENGINEERING

By

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ADVANCED SYSTEMS DIVISION
Wright-Patterson Air Force Base, Ohio 45433

December 1976
Final Report for Period April 1976 – December 1976

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This final report was submitted by Manned Systems Sciences, Incorporated, Westlake Village, California 91361, under contract F33615-76-C-0045, project 1124, with Advanced Systems Division, Air Force Human Resources Laboratory (AFSC), Wright-Patterson Air Force Base, Ohio 45433. Mr. Lawrence E. Reed, Personnel and Training Requirements Branch, was the contract monitor.

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

(19) REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER (18) AFHRL-TR-76-92	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle) (6) ASSESSMENT OF A PROTOTYPE HUMAN RESOURCES DATA HANDBOOK FOR SYSTEMS ENGINEERING	5. TYPE OF REPORT & PERIOD COVERED (9) Final rept. Apr[redacted] – Dec[redacted]76
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) (10) David Meister	8. CONTRACT OR GRANT NUMBER(s) (15) F33615-76-C-0045 new
9. PERFORMING ORGANIZATION NAME AND ADDRESS Manned Systems Sciences, Inc. 32107 Lindero Canyon Road, Suite 124 Westlake Village, California 91361	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 62703F (17) φ3 (16) 1124[redacted]
11. CONTROLLING OFFICE NAME AND ADDRESS HQ Air Force Human Resources Laboratory (AFSC) Brooks Air Force Base, Texas 78235	12. REPORT DATE (11) Dec[redacted]76
	13. NUMBER OF PAGES 104
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) Advanced Systems Division Air Force Human Resources Laboratory Wright-Patterson Air Force Base, Ohio 45433 (12) 196p.	15. SECURITY CLASS. (of this report) Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

engineering
handbook development
handbooks
human factors
human resources data

This study assessed

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The purpose of this study was to assess the effectiveness, utility and acceptability of a prototype human resources (HR) data handbook developed by the Air Force Human Resources Laboratory (AFHRL-TR-75-64, AD-A019 553). Twelve system development problems (representative of those the prototype handbook was designed to solve) were simulated in questionnaire form. Thirty-six engineers used the prototype handbook to solve these problems. They also rated problem difficulty level, their confidence in their solutions, the similarity of the problems presented to those they ordinarily dealt with, the usefulness of the prototype handbook, and the adequacy and accessibility of their own data sources compared to the prototype handbook. Results indicated that system development personnel can use the prototype handbook to significantly improve decision correctness. A substantial

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percentage of respondents considered the prototype handbook to have moderate or greater utility and potential influence on design. Recommendations for improvement of the prototype handbook were made. The assessment is sufficiently encouraging to warrant continuing the effort to develop HR data handbooks.

SUMMARY

1. PROBLEM

The purpose of this study was to assess the effectiveness, utility and acceptability of a prototype human resources (HR) data handbook (Reed, Snyder, Baran, Loy and Curtin, 1975) developed by the Air Force Human Resources Laboratory. HR data are data describing what people can do, how much they cost, their availability, and the need for them. A handbook of such data is needed by system development personnel because these data significantly influence the effectiveness and cost of the system and because available information is widely scattered throughout many sources.

Once such a handbook is compiled, the question is whether it will be effective and useful in terms of solving relevant problems, and just as important, whether it will be accepted by its eventual user. The user is generally someone untrained in a behavioral orientation. Hence, it is necessary to discover whether the material presented to him has been translated into his terms and whether he will make use of the handbook.

Such an assessment process is *particularly necessary* in the case of the prototype handbook because, although there have been other behavioral data handbooks of a molecular, human engineering character, the prototype handbook is the first that deals with human resources and behavior on a molar level.

2. APPROACH

Since the prototype handbook is compiled to be <u>used</u> in a particular context (in this case, system development), the most appropriate methodology would be to give it to potential users to employ the handbook in relevant work activities and then ask them to evaluate the prototype handbook.

This approach runs into practical difficulties, e.g., time required, limited observational opportunities, a small user population, the possibility of interference with ongoing development activities. The solution adopted was to obtain data from typical users during and after their use of the handbook to solve hypothetical or simulated system development problems.

Twelve representative problems based on prototype handbook parameters were included in a questionnaire format. Six of the problems compared a new system of indexing data (the Master Index) with the more familiar Alphabetical

Index. In these indexing problems, test participants (henceforth to be termed "participants," "respondents," "users" or "personnel" for short) were required to enter the prototype handbook and determine, by means of the indexing system specified, which handbook table would provide appropriate data. In these indexing problems, participants did not have to solve the problems.

In the remaining six data extraction problems, the page number of the correct table was given the participant along with the problem and he was required to use the table to solve the problem. In two of these problems, personnel were required to solve the problem first without, and then with, the aid of the prototype handbook, thus permitting a comparison of solution efficiency with and without the handbook.

Following each data extraction problem the user was asked to rate such factors as the difficulty level of the problem, his confidence in the correctness of his answer, the similarity of the problem presented to the ones he customarily encountered, and the usefulness of the prototype handbook data in solving the problem.

Following all 12 problems, participants were asked to rate the utility of the prototype handbook as a whole. Rating instruments were 5-point Likert-type scales.

Three criteria were applied to the assessment: handbook effectiveness (the user's ability to solve problems correctly and in reasonable time); handbook utility (whether handbook data were useful in solving problems); and handbook acceptability (ratings of handbook usefulness and influence in system design).

Participants came from two populations: 10 from System Program Offices (SPO) at Wright-Patterson Air Force Base (WPAFB), Ohio; 26 from the F-15 design organization at the McDonnell-Douglas Astronautics Company in St. Louis. This was to determine whether the prototype handbook was equally useful to SPO and contractor personnel. In both groups, participants varied widely in terms of specialty areas and years of experience.

The questionnaire was administered first at Wright-Patterson Air Force Base and subsequently at McDonnell-Douglas. No changes in the questionnaire between the first and second administration were necessary. At WPAFB, respondents were given the handbook and the questionnaire and allowed to complete the form ad libitum. At McDonnell-Douglas, they were issued the handbook and then assigned a scheduled meeting time during which to complete the questionnaire.

Data were analyzed by both parametric and non-parametric methods (the latter to check on the possibility that the non-normal distribution of responses might distort the analysis).

3. RESULTS

Although participants had little or no opportunity to study the prototype handbook before using it to solve questionnaire problems, they solved 68% correctly. Solution efficiency varied greatly among personnel: 25-92% correct (mean 64%) in the WPAFB sample; 46-92% correct (mean 70%) in the McDonnell-Douglas sample. Differences between the WPAFB and McDonnell-Douglas samples were not significant and consequently the two were combined.

Average task completion or solution time was around five minutes per problem, although the range was much broader than that for individual problems.

Personnel were significantly more correct in solving problems <u>with</u> than <u>without</u> the aid of the prototype handbook. On one of the two comparison problems, respondents felt that the problem solved without the prototype handbook was significantly more difficult than the same problem solved with the handbook. They also had significantly more confidence on problems solved with the aid of the prototype handbook than without that aid.

The perceived difficulty of the problems presented was rated at 3.6, very close to the indifference point (4.0). Indexing problems appeared to be significantly more difficult than data extraction problems. Participants found the task of discovering the correct table number to be greater than that of using the material in the prototype handbook. On the other hand, they were more efficient with indexing problems than they were with data extraction problems.

Forty-four percent of the participants considered the prototype handbook as having moderate or greater utility and 62% as having potentially moderate or greater influence on their design work. They felt that their own data sources were just as useful or only slightly less useful than the prototype handbook. On the other hand, participants felt that their own data sources were <u>less accessible</u> than the prototype handbook.

Those who felt the prototype handbook had utility and influence on design represented a broad range of engineering backgrounds, although concentrated in specialties that customarily require more analysis of personnel interfaces (e.g., Human Factors, Maintainability, Reliability,

Operations Analysis) than does general design engineering. Those who had worked on problems similar to those for which the prototype handbook was developed were more positive about the handbook.

Participants preferred to use the Master Index system of indexing in preference to the Alphabetical Index, but performed more effectively with the latter, presumably because they were more familiar with it. They also considered that the Master Index system was more difficult to use than the Alphabetical Index, in part because the problems that had to be solved with the Master Index were more difficult than those with the Alphabetical Index.

Participants recommended a number of improvements to the prototype handbook, including updating of data and making the indexing systems easier to use.

4. CONCLUSIONS

The results of this assessment study suggest the following conclusions:

a. System development personnel can use the prototype handbook to make significantly more correct decisions than without the handbook. Engineers have greater confidence in decisions made with the prototype handbook than without it.

b. If one considers that a substantial percentage of participants viewed the prototype handbook as having utility and potential influence on design, the audience for this handbook is potentially large. Engineers had some difficulty recognizing the kinds of problems for which the prototype handbook was designed as ones they ordinarily encountered, but considered these problems to be realistic. Engineers consider their own data sources almost as good as the prototype handbook, but much less accessible.

c. Those who saw utility in the prototype handbook and are hence more likely to use it are more likely to have specialized jobs (e.g., Human Factors, Maintainability, Crew Station Design) than general design functions. Those who have worked on problems of the type dealt with by the prototype handbook tended to be more positive to that handbook and are therefore more likely to use it.

d. Engineers preferred to use the Master Index system in preference to the Alphabetical Index, but experienced greater difficulty and performed less effectively with the former. The Master Index system can be used to facilitate prototype handbook use, but should be refined.

e. A number of improvements were recommended by assessment participants, including updating the data, simplifying the Master Index system, reducing verbiage in the tables and clarifying the implications of the prototype handbook data. These improvements are required to make the prototype handbook maximally useful.

The assessment was sufficiently positive to warrant continuing efforts to develop handbooks and/or data banks of HR data for use in the design of new systems and equipments.

PREFACE

This study was directed by the Advanced Systems Division, Air Force Human Resources Laboratory, Wright-Patterson Air Force Base, Ohio, under project 1124, "Human Resources in Aerospace System Development and Operation," and task 1124 03, "Human Factors Engineering Technology for Development of Weapon Systems." Dr. Ross L. Morgan was the project scientist and Mr. Lawrence E. Reed was the task scientist. The research was conducted during the period from 15 April 1976 through 31 December 1976 under contract F33615-76-C-0045. Mr. Douglass R. Nicklas of Manned Systems Sciences, Inc. was principal investigator.

The author wishes to acknowledge the many government and contractor personnel who contributed valuable suggestions throughout the course of the research. Special thanks are due Dr. Gordon A. Eckstrand and Dr. Ross L. Morgan who reviewed the manuscript. Mr. Lawrence E. Reed made significant inputs to the planning of the research and the writing of this report. Helpful recommendations and assistance were provided by many personnel from the Aeronautical Systems Division, Wright-Patterson Air Force Base, but the following must be singled out: Mr. R. J. Schiffler; Dr. J. W. Dorton; Mr. J. Keating; Mr. C. McLean; and Mr. C. Carroll. The assistance of Dr. W. R. Jones and Mr. M. Cobb of the McDonnell-Douglas Astronautics Company, St. Louis, Missouri was crucial in arranging for many of the engineers who participated in the study but who must remain anonymous. The study could not have been conducted without the latter and the author is deeply grateful for their cooperation.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

ASSESSMENT OF A PROTOTYPE HUMAN RESOURCES DATA HANDBOOK FOR SYSTEMS ENGINEERING

I. BACKGROUND AND PURPOSE

BACKGROUND

This study describes the assessment of a prototype handbook of human resources (HR) data (Reed, Snyder, Baran, Loy, & Curtin, 1975) developed by the Air Force Human Resources Laboratory.

Before describing this handbook, the purpose of its evaluation and the methodology employed, it will be helpful to provide the reader with the background of this study.

Repeated attempts have been made to provide system development personnel (primarily design engineers but also including human factors personnel) with compilations of behavioral data. One of the earliest was the justly famous "Human Engineering Guide for Equipment Designers" (Woodson, 1954, Woodson & Conover, 1964), which was followed by a spate of handbooks for various purposes (e.g., Parker & West, 1973). These, however, dealt with the relatively molecular aspects of man-machine performance, those subsumed under the rubric of human factors engineering. The prototype handbook evaluated in this study is the first, however, that deals with the more molar considerations of HR, which has been defined by Askren (1973) in the following manner: "Human resources data are those data which describe the people of an organization in terms of what they can contribute, how much they cost, how available they are, how perishable they are, and how many of them are needed."

Why is it necessary to assess a handbook of HR data and how is that assessment accomplished?

Rarely is the desirability of developing handbooks questioned. HR research which is directed at the solution of urgent system development, training and operational problems can have little value unless it is communicated to those who need the information. Since HR data are scattered among a great variety of sources, they are not readily available to the engineer or human factors specialist when needed. Without a single source the HR specialist has difficulty in finding and consolidating information into usable form.

The questions that do arise are very pragmatic ones: What information should be provided in a handbook; how should that information be presented for optimal use? If doubts are raised about the utility of a particular

handbook, these are not about the desirability of handbooks per se but reflect the possibility that the handbook in question may not provide the proper information, that the information may not be directed to the appropriate "target" audience or that the method of presentation may not be optimal. Because of these possibilities, it becomes necessary to assess the effectiveness with which the handbook accomplishes its purpose.

The assessment of HR handbooks centers around three questions:

(1) Can the intended audience for such a handbook (e.g., engineers, human factors specialists) use the handbook? That is, are the data phrased and presented in terms such that the intended audience can utilize the data to solve system development problems? Are the data relevant to the kinds of system development problems the intended audience usually encounters?

(2) Will the intended audience use the handbook? Engineers are not notorious for willingly applying behavioral data and incorporating behavioral inputs into development. Even the most popular handbook (Woodson & Conover, 1964) has only a comparatively small audience among engineers. One may question whether readership in the conventional sense of newspaper, magazine or novel circulation should be one of the criteria of behavioral handbook utility, since the solution of system development problems is not ordinarily based on popularity. Use of a handbook in even a few critical system development instances would presumably more than compensate for the labor, time and money required to produce that handbook. Nevertheless, one does wish to know what the likelihood is that certain data compilations will be used. No definitive answer to the question can be given, and any answer is at best a highly subjective estimate.

(3) What handbook improvements are necessary and desirable? Rarely does the first version of a handbook not need revision.

The first two questions have significant philosophical and methodological implications, as we shall see later. For one thing, they establish the criteria to be employed in performing the handbook assessment.

Our concern for determining whether its intended audience can use the prototype handbook to solve system development problems stems from the fact that the audience for HR data handbooks is composed, in addition to behavioral specialists themselves, of system planners, design and system engineers, operations analysts, reliability/ maintainability engineers, etc. It is necessary, therefore,

that special efforts be made to ensure that these users understand the data provided them.

Obviously, the information transmitted by the HR researcher must be understood by the latter. Here we encounter a formidable difficulty because the engineer has been trained in a physical, not a behavioral framework. From this arises the problem of translating behavioral information into engineering language.

Attempts have been made to determine those characteristics which behavioral data should have to appeal to engineers (Devoe, 1963, Sinaiko, 1963, Meister & Farr, 1967). Among these are heavy emphasis on quantitative data, graphics and tables. Alternative information formats have been exposed to engineers to determine their preferences (see Meister, 1971, for a review of such studies).

The necessity for translating inputs into engineering terms (whatever these are, and the concept is very vague) assumes that the engineer will be the prime manipulator of these inputs. The initiator of the HR input- the human factors specialist- is not ordinarily in a position to create his own design; he must work through the engineer. One of the concepts behind the development of behavioral handbooks for engineers is the idea that engineers should ultimately assume as many personnel design functions as possible.

Efficient integration of HR inputs into system development assumes that (1) the system development personnel are provided with required information; (2) they are willing to utilize that information.

The first assumption presupposes that (a) the information is provided to the proper personnel, and (b) the information is appropriate to the system development problem it addresses. Since system development is very complex, it has become highly specialized (e.g., reliability/maintainability, system, electronics, avionics, training, etc., engineers). It is possible that information addressing particular system development problems may be given to personnel who face entirely different problems. Handbook developers and assessors must therefore ask themselves: Just who will read and apply this handbook; what problems should the handbook address; is the information appropriate to these problems?

The second assumption--the willingness of system development personnel to use HR information--poses more serious problems because it is influenced by many factors not under the handbook developer's control. These factors include the engineer's personality, training, experiential background and attitudes toward behavior, behavioral

science and HR specialists. Obviously, if a handbook's intended audience refuses to accept the material presented, handbook utility is jeopardized.

It is often assumed that if the translation of HR inputs into engineering terms is accomplished, system developers will automatically endeavor to use these inputs. This is a logical assumption which may be negated by the idiosyncratic factors previously referred to.

Because the engineer is mainly responsible for incorporating HR inputs into design, he becomes the ultimate standard of the utility of HR data. It therefore becomes necessary to expose the prototype handbook to the engineer's own assessment.

Underlying efforts to persuade engineers to utilize HR data are a number of assumptions that should be examined critically by handbook developers (although this report does not pretend to do so in any depth).

1. System development personnel need HR data in order to perform tradeoff analyses that involve personnel. No one can logically quarrel with this concept.

2. The kind of HR data needed by system development personnel and the manner in which these data should be presented has been ascertained. To a certain extent data communication requirements for engineers have been fairly well established (graphics, numerics, simplicity, precision) and there have been attempts to determine the precise behavioral information the design engineer needs (Hannah & Reed, 1965; Meister, Sullivan, Finley & Askren, 1969a, 1969b). However, given the different backgrounds system development personnel have and the variety of development jobs they perform, it is difficult to match up the types of personnel with their specific needs for HR data.

3. Since the system/design engineer is the one who applies HR data to developmental decisions, his ability and willingness to use these data become the standard against which one assesses the adequacy of these data. The present study was performed on the basis of that assumption.

This is not an unreasonable standard. It is, however, affected by the engineer's training and idiosyncracies. Use of the standard requires one also to consider the implications of the engineer's failure to accept HR data. If these data are not accepted by their intended users, are they invalid or irrelevant?

HR data collected <u>under the proper conditions</u> can never be invalid in the sense of being unrepresentative of the conditions under which they were gathered, but they can be irrelevant in terms of the uses to which one wishes to put them. Different types of behavioral data are required for different purposes. For example, human engineering data are one distinct variety used for making bench-level design decisions, and there are some excellent human engineering handbooks (e.g., Woodson & Conover, 1964; Van Cott & Kinkade, 1975). It is possible that user reaction to these data determines whether the data are directed to the correct audience and deal with the appropriate questions.

On the other hand, reliance on positive user reaction to behavioral data as the criterion of data relevance means that the behavioral specialist's responsibility for determining the meaningfulness of his inputs to development is substantially transferred to the engineer. With the user's generally low level of application of behavioral inputs, is it realistic to allow his reaction to determine what inputs are given him? Ultimately one must ask whether non-behavioral personnel are qualified to sit in judgment on these inputs.

The following questions must therefore be addressed by handbook developers:

1. Who should be the primary audience for behavioral data handbooks? The behavioral specialist who then translates these data to other system development personnel? If so, the audience for the handbook is small and highly specialized. Should it be other system development personnel for whom the behavioral handbook seeks to perform the translation of behavioral inputs into engineering terms directly? In that event, what then becomes the role of the human factors specialist in system development? Should the handbook address both types of audience? Can one format data for two such different types of personnel in the same handbook?

2. Of system development personnel other than human factors specialists, is there a subset - those with distinctive backgrounds (engineering specialties such as maintainability, crew system design, etc.) - to whom the behavioral handbook should be directed? In other words, how broad should the targeted audience for the handbook be?

3. What kind of reaction signifies that the intended audience will in fact make use of the behavioral handbook? What does the developer expect the user to do with the handbook?

With these last questions we approach the problems involved in assessing the prototype handbook.

DESCRIPTION OF THE HR HANDBOOK

Although it is impossible to present complete details of the prototype handbook, it is necessary for the reader's understanding of this report to describe the outline of that handbook. The following material is taken (with some slight modifications) directly from the handbook (Reed et al, 1975).

The prototype handbook was prepared: (1) to assess the need for a technical reference containing HR data, and (2) to determine whether it was feasible to combine HR data obtained from many different sources into a format that conveyed meaningful information to potential users. The intention was to develop a limited handbook containing samples of data that must be given consideration in a full-scale handbook development program. Since this prototype handbook contains only a limited amount of data, the data do not present a complete picture of Air Force human resources utilization.

The prototype handbook contains data on manpower, personnel skills, training, maintenance performance, logistics and costs as they relate to, and interact with, operational systems and subsystems. Potential users of the prototype handbook include human factors specialists, training planners, design engineers, configuration managers, system planners, etc. The intent was to:

1. Consolidate HR data applicable to system design and development. These data are usually scattered in many government and contractor data banks, technical reports, operational commands, and in the form of expert opinion.

2. Assist the user to determine how human resources are influenced by system design and vice versa.

3. Provide a means by which specialists involved in system design and development can make optimal use of HR data.

4. Present data from different disciplines.

5. Provide a means by which design problems can be identified and resolved. The prototype handbook should allow design tradeoff decisions to take into account the constraints of the Air Force's human resources.

The prototype handbook is limited to data on the functions performed by the avionics career field on the fire control system of nine fighter systems. These systems include the F-106A/B, F-105D, F-4C, F-4D, F-4E, F-111A, FB-111A, A-7D, and the F-15. Naturally the prototype handbook does not contain all of the information that would be included in a full-scale handbook.

The prototype handbook is organized into three data sections and two indexing schemes. The three data sections are:

Section I - Empirical data on fire control systems. In general, this section contains comparisons between system designs, training, support manpower, occupational jobs/tasks, maintenance procedures, logistic support and various costs.

Section II - Human resources posture. This section contains information pertinent to past, current and projected numbers of personnel with various skill and experience levels.

Section III - General references. Included in this section are data on the effects of task complexity, the time required for Air Force maintenance personnel to acquire certain skills, error rates in performing maintenance activities, performance time, etc. With few exceptions, each data page in the prototype handbook contains a set of relationships that stands alone and is relatively self-explanatory. The upper third of the data page presents a set of functions, a table, function flow, bar chart or other form showing the pertinent data relationships. The contents of each table, shown in Figure 1, are:

1. Title.

2. Comments: A short description of the data, the methods used to collect the data, population sampled, definitions or other pertinent information.

3. Implications: A short summary of the possible implications of the data to Air Force system design, development, operations, etc.

4. Data Sources: A list of references from which the data were obtained.

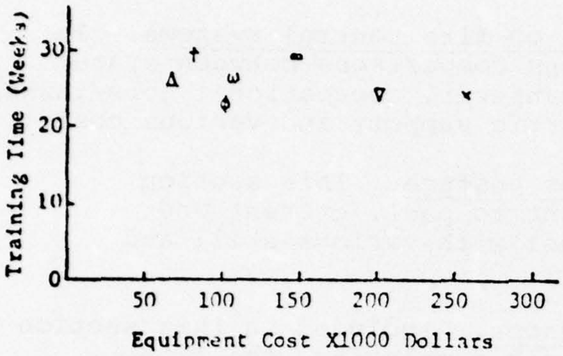
5. Models for Data Application: An index number(s) to a mathematical model(s) contained in Section III.

6. Subject: A short title of data contents with an emphasis on the key words appearing in the Master Index Tables of Content.

7. Index: The two major index numbers keyed to the Master Index.

8. Cross-index: A reference to a data page containing related information.

9. Page Numbers: The page numbers are keyed to the indexing scheme of this handbook.



Symbol	Equipment	* Mo.-Yr	Axes X X1000	Axes Y
Θ	F-106A/B	7-59		
†	F-105D	5-60	80	29
Δ	F-4C	5-63	55	26.6
ω	F-4D	12-65	101	26.6
●	F-4E	10-67	149	29.4
×	F-111A	10-67	255	24
∇	FB-111A	7-68	200	24
ϕ	A-7D	12-68	100	23
ε	F-15			

*Date Entered AF Inventory

TITLE: Relation of 3ABR32231 Training Time to Fire Control Radar Subsystem Acquisition Cost

COMMENTS: Course 3ABR32231 provides formal school training[1] for Semi-Skilled Level 3 Mechanics on Fire Control radar subsystems. Using equipment acquisition cost[2] as a single logical descriptor of technological sophistication (see Chart I.3-2.1), its relationship to training time was examined.

IMPLICATIONS: Data failed to yield significant findings. However, there was a moderate negative relationship, i.e., a tendency for training time to decrease as subsystem cost increased.

DATA SOURCES: 1. ATC/ACMF, Randolph AFB, Texas, October 1972.
2. USAF Logistics Command, Wright-Patterson AFB.

MODELS FOR DATA APPLICATION:	SUBJECT:	INDEX: 19-3
III.7-42.1(I)	Training Time vs. Fire Control Radar Subsystem Cost	CROSS-INDEX: I.3-2.1

Figure 1. Representative handbook data.

There are two procedures which can be followed to gain access to needed data. The first procedure (Master Index, or MI as it is abbreviated in this report) allows the reader to search for specific data relationships. If he is interested in determining the relationship which may exist between maintenance manhours and certain subsystems, he must turn to the MI and the MI Tables of Content. In its present form the MI was developed specifically for the prototype handbook because it presumably allows more efficient entry, permitting the user to go directly to the relevant data. The second (more conventional) procedure (Alphabetic Index or AI) provides the user with an alphabetical listing of major topic areas covered in the handbook. This listing is located in the back portion of the handbook.

The index number which identifies a table is composed of four numbered elements, each separated by a dash or period (e.g., I.11-9.5). The first element is a Roman numeral that identifies the section of the handbook. The next two elements in Arabic numerals are keyed to the Master Index. The first of these two elements is drawn from the numbers in the left-hand vertical margin of the Master Index and the second from the diagonal margin. (See Figures 2 and 3.) The last element, also in Arabic numerals, is keyed to the Master Index Tables of Content.

The procedures for finding needed data in the prototype handbook require three steps illustrated in Figure 2. Say that the user would like to know if there is a difference in maintenance manhours (MMH) for removal actions of fire control radar subsystems on the various fighter systems. First, the user must turn to the MI to determine whether this type of information exists in the prototype handbook. By scanning the left-hand margin he finds that maintenance manhour information is in Section I under the general subtitle, Operations, and has the index number 11. The user then matches this index number with one provided in the diagonal margin. For maintenance removal actions, the appropriate index number is 9. Thus, the appropriate cell in the Master Index is 11-9. The next step is to proceed to the MI Tables of Content located immediately following the MI page. The index numbers at the top of each table are in sequential order and match those in the cells of the MI. In the example provided here, the user seeks Table 11-9 for Section I data and finds that the needed information is on Page I.11-9.5. The last numeral of the index is found under the appropriate column of the table.

The procedures above can be summarized as follows:

1. Determine the section number in which the needed data may be found.

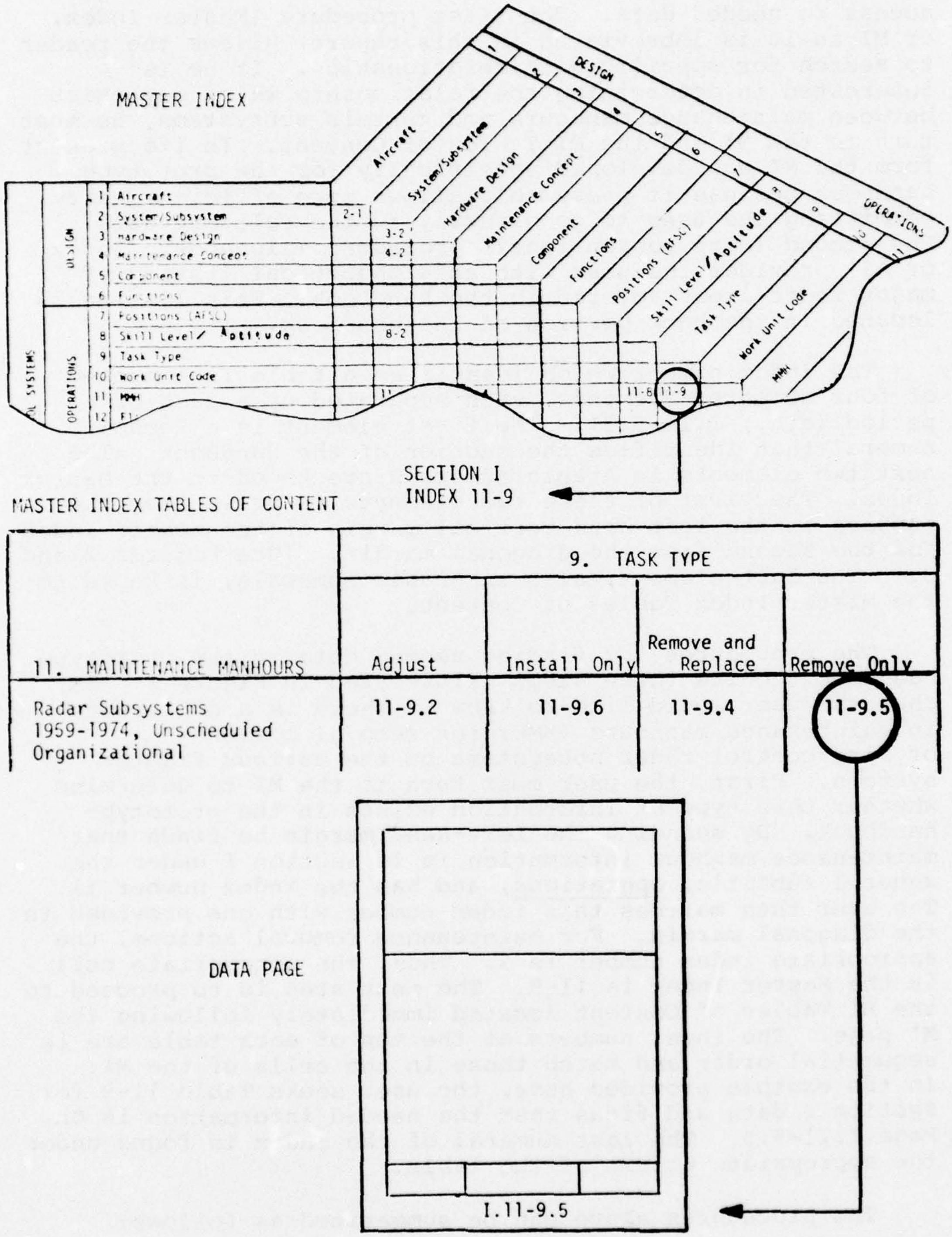


Figure 2. Steps to find data.

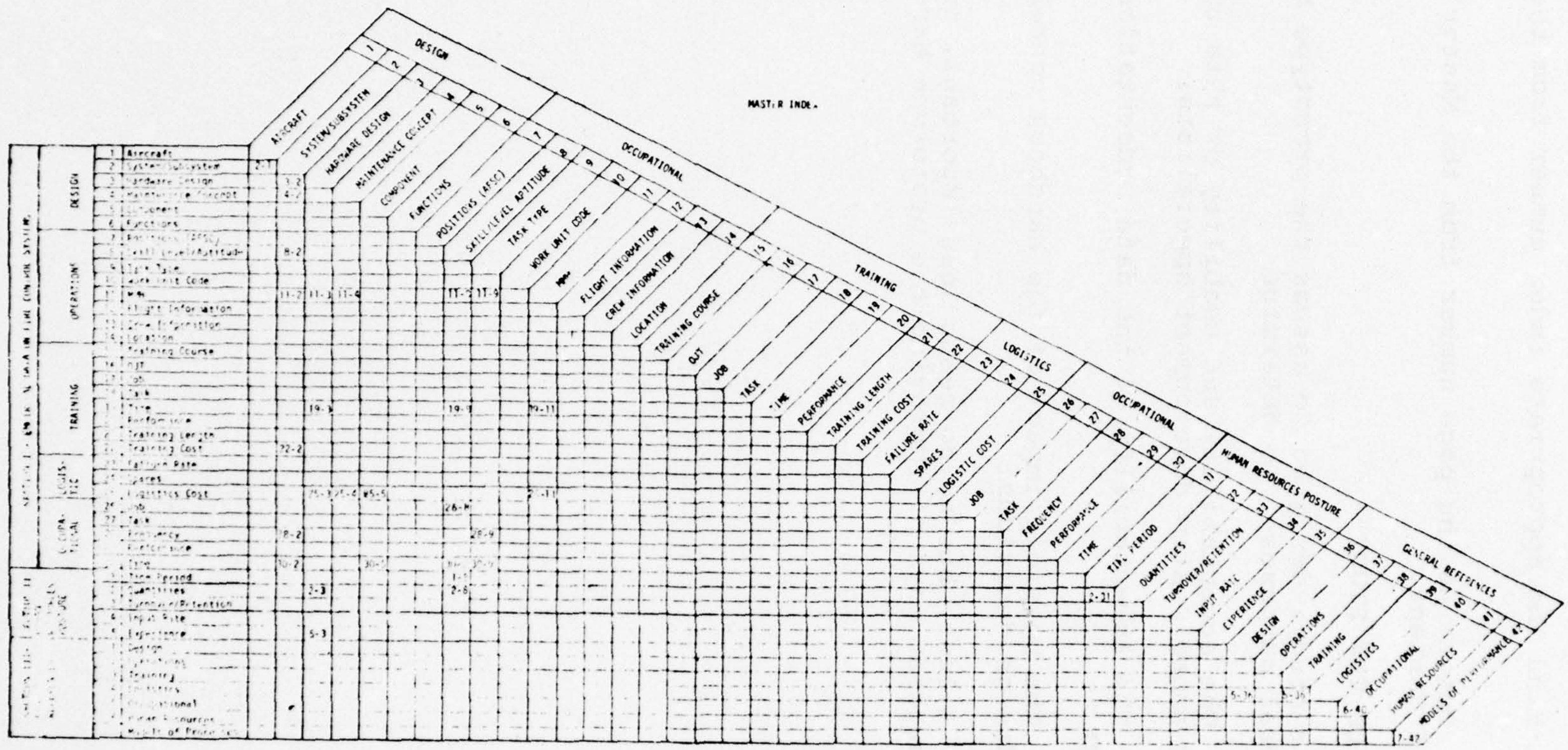


Figure 3. The master index.

2. Find the appropriate index number from the Master Index.

3. Determine the page number from the Master Index Tables of Content.

PURPOSE OF THE STUDY

This study, designed to assess the prototype handbook, had several purposes: To determine

1. The acceptability and usability of this type of handbook among system development specialists;

2. The acceptability of the data presentation and indexing;

3. The possible impact of the handbook concept on system design decisions.

4. A last, but by no means less important, purpose was to suggest ways of improving the prototype handbook.

II. METHODOLOGY

INTRODUCTION

The general methodology for assessing the prototype handbook had several introductory steps which involved determination of:

1. The general assessment methodology;

2. The assessment criteria to be employed;

3. The format of the assessment instrument;

4. The type of user/participant to whom the assessment instrument was to be administered.

Before proceeding further, it is important to consider these factors.

GENERAL ASSESSMENT METHODOLOGY

A prototype handbook can be assessed in two ways. One can submit the handbook to a reviewer who need do no more than read the material and present his opinion about its adequacy. Essentially this is the way most textbooks and novels are assessed.

Alternatively, since the prototype handbook, unlike a novel, was designed to be used in a particular context (system development), one could give the handbook to potential users and ask them to employ it in their customary work activities.

The latter would be ideal, but unfortunately it runs into practical difficulties. Opportunities for using the prototype handbook in actual system development might occur only erratically; therefore, the time involved in gathering the desired information would probably be prolonged. The difficulties of extracting the necessary assessment information from on-going activities might make heavy demands on users as well as possibly hindering actual development. Only a relatively few users could be tapped for their responses.

An alternative solution would be to simulate in paper-and-pencil mode the kinds of system development activities in which the prototype handbook would be used; and to require personnel to use the handbook in performing these simulated activities.

This procedure, which was followed by Meister & Farr (1965) in a previous study of designer reactions to human factors inputs, was employed also for this study. Since the prototype handbook was designed to be used in solving system development tradeoff problems involving personnel (as well as other parameters), a series of such problems was devised. To make use of the prototype handbook, these problems had to reflect the parameters and data available in the handbook. The system design/tradeoff situation was simulated by a series of miniature design "cases" which presumably called upon the behaviors the participant would employ in the actual situation. Such problems might take the following general form:

> Assume you are a system designer who is faced with a number of alternative means of implementing the system (which are then described). The system has such and such characteristics (e.g., varying levels of automation). What degree of automation will enable you to reduce the required personnel skill level and at what level will savings based on reduced skill equal the increased cost of automation?

One may ask whether the developmental situations simulated are indeed representative of those found in actual development. If they are not, then even if the prototype handbook can be used effectively in the assessment setting, it will not necessarily be effective in actual development.

The question of problem "fidelity" creates methodological difficulties for the assessment. Obviously, the assessment problems must reflect handbook parameters. One would not, for example, provide an encyclopedia of church history as an aid in solving system development problems. On the other hand, the prototype handbook does not deal with all types of system development problems; in particular it does not provide data related to molecular, human engineering (e.g., "knobs and dials") problems.

One might of course ask participants whether the problems presented to them are those they ordinarily encounter during system development. If they answer yes, then the question of problem fidelity is answered satisfactorily. Suppose, however, they answer no, or rarely. Are the prototype handbook parameters as reflected by these problems then invalid? With a broad spectrum of users and the fact that system development presents them with problems at varying levels of complexity,

one would expect that some users would never or only rarely have encountered these problems.

The parameters in the prototype handbook describe empirical data relationships derived (largely) from Air Force records. Consequently, they are inherent in system development, although any particular group of system development personnel might not be required to deal with these parameters. Indeed, without a source such as the prototype handbook the opportunity to deal with such parameters probably would not be available. Engineers might be aware, for example, of the question of whether enough personnel of the specified type would be available for their new system; but this question ordinarily would not be presented to them as a problem to be solved because means (i.e., the prototype handbook) of answering the question or of including the factor of personnel availability in design considerations would not be available to them. One must therefore rely ultimately for the answers to the question of handbook validity on what has been termed in other contexts "construct validity."

ASSESSMENT CRITERIA

The questions posed by the assessment require various criteria. The question," <u>can</u> system development personnel use the prototype handbook?" requires <u>effectiveness</u> and <u>utility</u> criteria; the question, "<u>will</u> they use the handbook?" requires criteria of <u>acceptability</u> to users. The three criteria can be measured both <u>objectively</u> and <u>subjectively</u>.

1. Prototype handbook <u>effectiveness</u> is defined by the participant's employment of the data presented to derive meaningful decisions. He might of course arrive at a decision with no aid but his own experience; that, after all, is the method many system development personnel employ. If the prototype handbook is efficient, however, the decision the user arrives at with its aid should be substantially more effective- more precise, more accurate- than the one he achieves without the handbook. He should be able to arrive at a decision in a reasonable period of time. He should have more confidence in a decision based on the prototype handbook; a problem solved with the aid of the prototype handbook should seem less difficult than the same problem solved without the handbook. In order to demonstrate these points two things are necessary: (1) any problem requiring a design decision must have an objectively correct response (as defined by the data in the prototype handbook), with other responses being either incorrect or less correct than the one specified; (2) users should have the opportunity to solve design trade-off problems with and without the HR handbook.

In a study conducted by Lintz, Loy, Brock & Potempa (1973), problems were presented to users with alternative configurations to be selected. A procedure somewhat similar to this might have been utilized in the development of the assessment problems. For obvious reasons, however, it was impossible to provide the variety of information supplied by Lintz et al or to give participants the same length of time to analyze problems. Nevertheless, every care was taken to create system development situations which would differentiate between decisions made using the HR handbook and those made without using it.

To facilitate this comparison certain problems required use of the prototype handbook; others did not; decisions made under the two conditions could then be systematically compared. Ideally one would wish to be able to say for example that under condition A (no HR handbook) 26% of decisions were correct, whereas under condition B (using the HR handbook) 76% of decisions were correct.

2. Prototype handbook utility was measured subjectively, by asking participants to report whether handbook data were useful in solving individual problems; and to compare the usefulness and accessibility of their own data sources with the prototype handbook.

3. Prototype handbook acceptability was measured by having users rate the usefulness that an improved HR handbook would have in their work and the degree of influence it would have in system design.

How does one define these criteria in quantitative terms? Is 50% correct solution of problems adequate? 75%? 85%? Is a rating of moderate utility for the prototype handbook satisfactory, or does one require a rating of extremely useful? Obviously, no absolute quantitative value can or should be specified. The quantitative data reported in Section III of this report must be considered, however, in the context of the engineer's general usage of behavioral data which, even for traditional human engineering topics, with which he has been familiar for a quarter-century, is not great.

QUESTIONNAIRE FORMAT

As must be apparent by now, it was determined that the assessment format should take the form of a questionnaire containing a series of problems to be solved. Certain of the problems would address the question of which indexing system was preferable (indexing problems); others would determine how well participants could extract data from the handbook tables (data extraction problems); a special set of problems would compare problem solution with and without the prototype handbook.

Each problem to be solved was supplemented by questions (usually in the form of a 5-point Liker-type scale) asking the participant to rate factors such as the difficulty he experienced in solving the problem, his estimate of the correctness of his solution; the degree to which he had encountered in his real-world job problems similar to those presented to him.

A final section of the questionnaire asked questions relating to the prototype handbook as a whole, e.g., the user's estimate of the utility of the handbook as a whole.

The questionnaire will be described in detail later.

USER PARTICIPANTS

The selection of personnel for this assessment was critical, since one of the major criteria in the assessment was the acceptance by participants of the need for the prototype handbook. As indicated in Reed et al (1975), "Any handbook development problem must have an identified set of potential users... Engineers of different specialties, system planners, etc., may have a need for human resources data, but their requirements will differ..." (p. 15). Unfortunately, "Many specialists feel no pressing need for... (HR) .. data, or are totally unaware that the data exist" (p. 16). Participants who lacked an awareness of HR data or felt no need for it might provide a misleading picture of the prototype handbook's utility. In any event, the target audience for the prototype handbook was limited to those involved in the design and development of fire control subsystems.

Early in the planning of the study it was decided that the potential participants who would have the greatest use for- and therefore appreciation of the utility of- the prototype handbook would be those that were responsible for "high level" decisions involving tradeoffs between personnel and other engineering factors.

The identification of specific individuals performing such functions is very difficult. One might find them in Air Force system development and headquarters planning staffs, but such personnel are not readily available as study participants. One might also find them in companies responsible for development of major sophisticated systems.

Since the prototype handbook was developed to be used by both Air Force and contractor personnel, the following strategy was adopted. Two samples were selected, first, from personnel attached to System Program Offices at Wright-Patterson AFB (WPAFB), the second from engineers working on the F-15 aircraft development at McDonnell-Douglas Aerospace

Company (St. Louis, MO). These two samples permitted a test of the question whether the prototype handbook was conveying information of the same effectiveness and utility to both sets of users. Because of the broadness of the sample, it would probably include engineers who were not among the target user audience. The purpose of the broad engineering spectrum was to try to isolate those types of system development personnel who would find the prototype handbook of greatest use.

One last point, it is necessary to emphasize that the problems presented were to assess the handbook, not to test the engineers' ability to solve the problems.

THE QUESTIONNAIRE

The questionnaire, as finally developed, is presented as Appendix A. It consists of 12 problems that were developed to utilize a representative sample of the data items in the prototype handbook. Problems were extracted from all three sections of the handbook.

1. Handbook Effectiveness. Six of the problems compared the Master Index (MI) and the Alphabetical Index (AI) to determine which indexing system was more effective. Problems 1 and 7 required participants to use the MI to determine the table appropriate to the solution of the problem presented. Problems 8 and 11 required the participant to use the AI to do the same thing. Problems 3 and 4 required the participant to choose between the MI and AI in finding the correct table.

In the indexing problems the participant was merely required to determine the number of the appropriate table. In indexing problems the subject did not have to solve the problem.

Problems 2, 5, 6, 9, 10 and 12 were data extraction problems. These were identical in type to indexing problems but called for their solution. In these items the participant was given the number of the table that contained the data for problem solution. Each data extraction problem had only one relevant table (the one specified in the problem). No cross-indexing of handbook data was required.

Answers to all problems were quantitative and could be derived directly from the tabular material in the prototype handbook. No problems were presented that could be solved merely by expression of opinion; e.g., design configuration A is better than (or to be preferred to) B. Such problems were avoided, since they could not be objectively scored.

Problems 5 and 9 were devised with a special format to permit a comparison of solutions "without" and "with" the prototype handbook. Participants were asked to solve these problems first without reference to their prototype handbook. They then were asked (on the following page of the form) to open their prototype handbooks to the specified table and resolve the problem, either to confirm their original answers or to find a more correct one. The correctness with which the problem was solved under the two conditions could then be compared.

(Why did participants not cheat by looking immediately at the number of the correct table and solving the problem in that way? Observation suggests that they did not do so and the data indicate that this was highly unlikely, since many participants failed to solve the problem in the "without" condition.)

Each problem had of course only one correct answer as defined by the relevant handbook table. However, partial credit was given because it is possible to enter the prototype handbook at varying levels of efficiency. Thus, in extracting data from a handbook table one can secure an approximate as well as precise answer. For example, if his answer to problem 1 (an indexing problem) was I.26-8.4, he received full credit (score of 1.0). If he recorded I.26-8, he received half credit (0.5). If he merely identified the correct table as being in Section I (or recorded no answer at all), he received zero credit (0.0). The system of partial credit was adopted for all 12 problems.

The participant was also asked to indicate to the nearest minute the time he started the problems and when he completed it. This permitted comparison of the time required by each of the various conditions.

Following each data extraction problem (2, 5, 6, 9, 10 and 12) the following questions were asked:

a. How easy or difficult was the problem to solve? (This measure is identified in Appendix B as Problem Difficulty, q. 1.) Problem difficulty is an obvious measure with which to differentiate between MI and AI, and between the "with" and "without" conditions of problems 5 and 9. Moreover, the absolute level of difficulty the participant experienced is one way of evaluating prototype handbook utility; if perceived difficulty is too great, handbook utility is reduced.

b. How certain are you about the correctness of your answer? (Solution Certainty, q. 2.) Personnel might be more or less confident about their decisions depending on the conditions they were exposed to.

c. In your work have you encountered problems similar to the one you have just solved? (Problem Fidelity, q. 4.) One way of assessing the effectiveness with which engineers can use the prototype handbook is in terms of the representativeness of handbook parameters.

2. <u>Prototype Handbook Utility</u>. Questions dealing with handbook utility included:

a. If in your work you encountered a problem similar to the one you have just solved, would the material in the tables have been useful in solving that problem? (HR Data Utility q. 5.) This measure of handbook utility is for the immediate problem being solved.

b. For this problem how useful would your own data sources be compared to the prototype handbook? (Own Data Utility, q. 7.) If the user considers his own data sources as useful as that of the prototype handbook, he is less likely to use that handbook.

c. For this problem how accessible would your own data sources be compared to the prototype handbook? (Own Data Accessibility, q. 8.) Accessibility of own data sources is another way of assessing handbook utility. If the engineer's own data sources are less accessible than the prototype handbook, he is more likely to use the handbook.

3. <u>Prototype handbook acceptability</u>. Questions dealing with handbook acceptability are to be found at the end of Appendix A and are also listed in Appendix B as items A-D.

a. How useful would an improved version of this type of handbook be in the work you do? (Hdbk Utility, Item A, Appendix B.) This question is related to the one on HR Data Utility (q. 5) but deals with the prototype handbook as a whole.

b. How influential would an improved handbook of this type be in affecting your system design decisions? (Hdbk Influence, Item B, Appendix B.)

c. How often have you used human resources data in your work? (Use of HR data, Item C, Appendix B.)

d. How important do you consider human resources and human factors in operation and maintenance of avionics and fire control equipment?

e. How important do you consider human resources data in affecting system design?

In analyzing the resultant data, these last two questions were combined under the heading of HR Importance (Item D, Appendix B.)

4. Prototype Handbook Improvement. Participants were also asked for which of a number of subject areas could such a prototype handbook be used effectively, and what would they recommend to improve the handbook?

In addition to the above questions, the participant was given a checklist that listed any difficulties he might have experienced in solving the problem. He was also asked to indicate where he got the data he currently used to solve such problems. He was asked to comment on any aspect of the problem that had given him difficulty.

For indexing problems the participant was asked the following questions:

1. How easy was it to use the MI (or the AI) in finding the correct table?

2. What words did he use to enter the index?

3. How easy was it to perform the individual steps of the MI procedure, or (for the AI) if he found AI difficult to use, he could check one of several possible reasons?

Following the series of 12 problems, the participant was asked to rate the usefulness of the individual sections of the handbook tables; did the tables provide as much data as he wished and if not, what additional data did he wish?

In responding to the above questions personnel were given a 5-point Likert-type rating scale. (It was felt that users would be confused by a more complex scale.) For example, the ease/difficulty dimension had as major descriptors: very easy; easy; neither easy nor difficult; difficult; very difficult. The certainty dimension ran from completely certain (1.0) through very certain (2.5); neither very certain nor very uncertain (the indifference point, 4.0); very uncertain (5.5); and completely uncertain (7.0). In all cases (except those dealing with own data utility and accessibility) the positive answer to the question ranged from 1.0 to 4.0. Examination of Appendix A questions will indicate the various descriptors that were used for the individual scales.

MEASURES

The questionnaire thus permitted the following measures which the reader should keep in mind in reading Section III of this report.

1. Percentage of problems correctly solved for categories of problems and types of users.

2. Mean and Standard Deviation (SD) correctness score for individual and total problems and mean and SD for a category of problems (e.g., MI vs AI).

3. Mean and SD of solution times (minutes) for the individual problem, for a category of problems and for participants.

4. Mean rating and SD for individual questions, for individual problems and for categories of problems and participants.

5. Percentage of personnel rating questions at a specified level (e.g., 4.0 or less).

6. Percentage of personnel choosing MI or AI on problems 3 and 4.

7. Frequency of checklist items checked, as in recommendations for improvement (q. 7, p. 31, Appendix A).

PARTICIPANT BACKGROUND

The specialty areas of engineers selected as participants for this study and their years of experience are presented in Table 1. Individual user background data are presented in Appendix B.

METHOD OF QUESTIONNAIRE ADMINISTRATION

Three methods of questionnaire administration were possible:

1. <u>One-on-one interviews</u>. This is the ideal method and was used by Meister & Farr (1966) because it permits one to explore in greater detail idiosyncratic responses. The drawback is the inordinate length of time required to secure a reasonable data sample. Under the conditions of this assessment, interviews were not practical.

2. <u>Group administration</u>. Participants are gathered together in small groups of 4 or 5 and the questionnaires are administered by the investigator. The advantage here is that any queries can be answered immediately, participant performance can be monitored, and the group administration creates an atmosphere of seriousness. This method was used with the largest number of participants.

3. <u>Ad lib administration</u>. Questionnaires are handed (or mailed) out and respondents are permitted to complete

TABLE 1. PARTICIPANT SPECIALTY AREA AND EXPERIENCE

	No.	Specialty Area	Years of Experience
WPAFB	2	Human Engineering/Human Factors (HE/HF)*	10, 15
	2	Maintainability (Maint.)	3, 4
	3	Avionics (Avion.)	8, 18, 20
	1	Aerospace Ground Equipment (AGE)	4
	2	Design Engineer (Design)	(did not answer)
Total:	10		
McDonnell-Douglas	3	Human Engineering/Human Factors (HE/HF)	9, 18, 35
	3	Maintainability (Maint.)	1, 10, 18
	2	Training (Train.)	23, 32
	1	Reliability (Rel.)	15
	2	Crew Systems Design (Crew)	6, 21
	3	Aerospace Ground Equipment (AGE)	16, 18, 26
	1	Avionics (Avion)	14
	1	Operations Analysis (Ops. An.)	14
	7	Design Engineer (Design)	8, 10, 12, 25, 25, 25, 35
	3	Miscellaneous (Misc.)	1, 5, 11
Total:	26		

*See categories in Appendix B.

the forms as time becomes available for this purpose. This method was employed with a small number of respondents at WPAFB. All participants had an opportunity to review the prototype handbook before they completed the questionnaire. To ensure that all started on the same minimal level, a half hour indoctrination preceded the administration of the questionnaire. The briefing included discussion of the purpose of the assessment, the nature of HR data, the two indexing systems and the nature of the material covered by the prototype handbook. All user questions were answered.

The questionnaire was then completed under the investigator's scrutiny and any further questions answered. ll participants were identified only by code numbers. They worked at their own speed and handed in their forms when completed. In general, completing the questionnaire took an average of 1.5 hours, with a few respondents working an additional half hour. The investigator's observations suggest that all participants were unusually assiduous and serious in completing their questionnaires.

SECTION III

ANALYSES AND RESULTS

INTRODUCTION

The data on which the analyses in this section are based are presented in Appendices B and C.

Appendix B lists individual participant responses to the questions in the assessment questionnaire; Appendix C lists the same data summarized across participants by problem.

Before proceeding to the analyses it is desirable to examine the characteristics of the data because these bear on the statistics employed. In order to make use of parametric statistics (e.g., Student's $\underline{t}$ and Pearson's $\underline{r}$) the size of the sample should be around 25-30 and the assumption of distribution normality (at least) must be satisfied. The size of the data sample in this study is 36 (assuming that data from WPAFB and McDonnell-Douglas can be combined--and a test of this point showed it could be combined). However, the assumption of normality of distribution appeared questionable upon inspection. This would appear to dictate use of non-parametric statistics, although parametric techniques would be preferable because of their ability to extract the full value of the available data.

Rather than lose the value of parametric statistics, the following strategy was employed. The validity of each statistical test making use of parametric statistics was checked by performing a corresponding appropriate non-parametric test. If the non-parametric test results did not controvert the parametric, the parametric test results were reported. (All non-parametric tests validated parametric ones.) On the ground that parametric tests exploit the data more fully, non-parametric checks were not made for any parametric test result that was non-significant. Thus, if a $\underline{t}$ or Pearson $\underline{r}$ were found to be non-significant, it was assumed that a corresponding appropriate non-parametric test would also indicate non-significance. (This assumption was checked out on a sample of the tests made.)

Section III has been organized in terms of the questions this study sought to answer:

1. Can engineers use the handbook to solve the types of HR problems for which the handbook was developed?

2. Will engineers use the handbook?

3. Which types of engineers (i.e., defined by their specialty area) are most likely to use the handbook?

4. Which of the two types of indexing systems do engineers prefer and which can they use more efficiently?

5. How should the handbook be improved to render it more useful and acceptable?

CAN ENGINEERS USE THE HANDBOOK

Data to answer this question come from two sources: (a) the percent of the 12 problems presented that engineers solved correctly; (b) the average time taken to solve these problems.

Percent Correct

Although participants had little or no opportunity to study the handbook before using it to solve the problems, they solved 68% of the problems correctly. Review of Appendix B indicates very great variability among personnel; for participants 1-10 from WPAFB the range was 25-92% (mean 64%); for 11-36 from McDonnell-Douglas the range was slightly more constricted: 46-92% (mean 70%).

Because the group from WPAFB numbered only 10, the non-parametric Mann-Whitney U-test (Siegel, 1956) was used to compare the correctness scores of the two groups to determine whether these could be combined. The difference between the two groups was insignificant ($p = .23$). Consequently, all further data analyses use combined data ($N = 36$).

One may ask whether a mean of 68% correct means that the handbook can be used effectively. In view of the absence of prior training to use the handbook, and the fact that most respondents were somewhat unfamiliar with the type of problems presented (see subsequent discussion on Problem Fidelity), the answer to that question appears to be yes.

The handbook user must perform two essential functions: (1) to determine where the data relevant to his problem are to be found in the handbook; (2) to extract from these data, once found, those principles, guidelines or implications that will enable him to solve the problem successfully.

The efficiency of the first function could be determined by studying responses to the indexing problems (1, 3, 4, 7, 8, 11); that of the second function, by examining responses to the data extraction problems (2, 5, 6, 9, 10, 12). If one type of problem were solved more

effectively than the other, this might suggest where emphasis should be placed in improving the prototype handbook.

The *t* test (Guilford, 1965) for correlated data (t_{dep}) was used to test the difference between <u>total scores</u> per participant for indexing problems (mean 4.4, SD .94) and data extraction problems (mean 3.5, SD .14). The *t* value was 4.06 (35 df) which is significant at better than the 1% level. Participants were significantly more efficient in finding correct tables than in extracting data from them.

The difference in performance between the two types of problems may have resulted in part from problems 5 and 9 which were considerably more difficult for participants than the other two data extraction problems.

To test this point and to confirm that indexing problems were in fact more efficiently solved than data extraction problems, problems 5 and 9 were eliminated from the data sample for this analysis and the difference between the <u>mean correctness percentage</u> of indexing (77%) and data extraction problems (67%) was tested, using t_{dep}. This test confirmed that indexing problems were in fact solved more effectively (t_{dep} = 2.32, 33 df, significant at the 5% level).

Problems 5 and 9 were specifically developed to determine whether the "with" handbook condition would produce more correct solutions than the "without" condition. The results of a t_{dep} test between the two conditions are shown in Table 2.

In both cases performance was significantly superior when respondents were permitted the use of the handbook. The effect was substantially greater with problem 9.

TABLE 2. CORRECT SOLUTIONS WITH AND WITHOUT HANDBOOK

	Problem 5		Problem 9	
Measure	Without	With	Without	With
Mean Correct Score	.22	.40	.03	.54
SD	.31	.32	.17	.48
t_{dep}	2.99		6.03	
N	31		32	
Sig. Level	.005		.0005	

It might appear obvious that if participants were permitted use of the handbook to solve these problems, solutions would in fact be more efficient. However, this depends on whether the necessary information can be extracted from the handbook. A number of respondents did not improve their solutions with the aid of the prototype handbook. It is possible that the prototype handbook will be most useful for those who have had least experience in solving HR problems.

Solution Time

Task completion or solution time is also indicative of efficiency in solving problems. On the average, problem solution time was around 5 minutes, although the range was much broader than that for individual problems. Again, no significant differences were found between the WPAFB group (mean 5.9 minutes, SD 1.4) and that from McDonnell-Douglas (mean 5.7 minutes, SD 1.6). The Mann-Whitney U-test for differences in mean solution time resulted in a p of .37, which is obviously not significant.

Were there significant differences in solution times between indexing problems (mean 6.0 minutes, SD 2.0) and data extraction problems (mean 5.4 minutes, SD 1.6)? The t_{dep} value is 1.96 (34 df) which just misses significance at the 5% level. The slight difference in completion time favors data extraction problems over indexing problems. The difference suggests that indexing tasks may have been more difficult for participants than data extraction tasks, a point which is confirmed in the next sub-section.

Problem Difficulty

Efficiency in solving problems must be considered in terms of the perceived difficulty of the problems presented (see Problem Difficulty 9.1, in Appendices B and C). This was rated on a five-point scale ranging from very easy (1.0) to very difficult (7.0). Mean difficulty rating for the 12 problems was 3.6 with a SD of 1.5, very close to the indifference point (4.0). Indexing problems (mean 3.7, SD 0.9) appeared to be significantly more difficult (t_{dep} = 5.62, 34 df, .01 level) for personnel than data extraction problems (mean 3.0, SD 0.7). This suggests that participants found the problem of discovering the correct table number to be greater than that of using the material in the table. On the other hand, they were more efficient with indexing problems than they were with data extraction problems. Again, there are wide individual differences.

One could hypothesize that problems solved without the use of the prototype handbook (the "without" condition of problems 5 and 9) would be considered by participants more difficult than the same problems solved with the handbook.

This proved to be the case for problem 5 (t_{dep}= 2.04, 29 df, significant at the 2% level), but not for problem 9. The hypothesis that use of the prototype handbook would reduce the apparent difficulty of HR problems is therefore partially supported.

Solution Certainty

Similar results are found for participants' feeling of certainty about the correctness of their solutions (see Appendix C, q. 2). This question was asked only of data extraction problems. The mean rating of certainty was 3.7, with a SD of 0.8. Again, these results are close to the indifference point, although there are wide individual differences among personnel and also among problems. For example, mean solution certainty for problem 10 was 2.7 which indicates substantially greater certainty than that felt for other problems, particularly problem 9.

Certainty is important in comparing the with and without conditions of problems 5 and 9. This is based on the assumption that one of the effects of having a handbook to help solve HR tradeoff problems would be to increase personnel confidence in their decisions. This is graphically confirmed in Table 3 in which a lower rating indicates greater confidence.

TABLE 3. SOLUTION CONFIDENCE WITH AND WITHOUT HANDBOOK

	Problem 5		Problem 9	
Measure	Without	With	Without	With
Mean Certainty Rating	5.4	3.0	5.3	4.1
SD	1.5	1.0	1.4	1.4
t_{dep}	7.83		3.84	
N	32		32	
Sig. Level	.01		.01	

WILL ENGINEERS USE THE HANDBOOK

Even if data are valid, if engineers will not use these data, their utility is negated. A number of measures bear on this point. These are: (1) Problem Fidelity (q. 4); (2) HR Data Utility (q. 5); (3) Own Data Utility (q. 7); (4) Own Data Accessibility (q. 8).

Problem Fidelity

Question 4 in the questionnaire asked whether participants had encountered problems similar to the one they had just solved. The problems in the questionnaire were derived directly from the handbook material and hence indicate the kinds of problems for which the handbook will be useful. If engineers find the questionnaire problems different from those they ordinarily encounter, they may not find the handbook relevant to their work. The question of problem fidelity was asked only of data extraction problems because only for these were personnel required to utilize tabular material.

Mean problem fidelity was 5.6, SD 1.1. On the scale of 1.0 (similar problems constantly encountered) to 7.0 (similar problems never encountered), the mean rating suggests that respondents had some difficulty recognizing the problems presented as ones they ordinarily encountered. Only 4 of the 36 participants were positive on this scale (at or below the neutral point, 4.0). The engineer typically encounters his problems in graphic or quantitative (e.g., tabular) form. Much of the problem unfamiliarity arose because the questionnaire problems were exclusively verbal.

HR Data Utility

Even assuming that the handbook problems were unfamiliar to most participants, one must still ask whether, if they did encounter such problems, the handbook material would have been useful. Data on this point can be found in Appendices B and C (HR Data Utility, q. 5). Responses to this question are more positive, the mean being 3.5, SD 1.0. This translates to a rating of moderately to very useful.

Own Data Utility

The utility of the handbook can also be assessed in terms of its relationship to the engineer's own data sources. If the engineer's own data (regardless of what these might be) are considered by him to be as useful as handbook data, he is less likely to make use of the handbook. Again the answer is somewhat negative (mean 4.7, SD 1.2), the subjects considering that their own data are just as useful or only slightly less useful than handbook material.

The responses to the question on Own Data Utility probably represent a deep conservatism on the part of engineers who prefer their own familiar data sources (no matter how deficient) to those they are unfamiliar with. This is a problem that the handbook developer (and the human factors engineer also) must constantly cope with. We shall consider this problem more completely in the Discussion section.

Own Data Accessibility

On the other hand, many engineers feel that their own data sources are less accessible than the handbook material. On question 7, Own Data Accessibility, the mean rating is 5.2, SD 0.9. This rating is significantly different from that of own data utility as shown in Table 4.

TABLE 4. COMPARISON OF OWN DATA UTILITY AND ACCESSIBILITY RATINGS

	Own Data Utility		Own Data Accessibility
Mean Rating	4.7		5.2
SD	1.1		0.9
t_{dep}		4.30	
N		33	
Sig. Level		.01	

The greater accessibility of handbook material compensates somewhat for the engineer's preference for his own data.

Handbook Utility as a Whole

The previous questions dealt with the utility of the handbook as it related to specific problems. At the conclusion of the evaluation participants were asked to indicate how they felt about the utility of the handbook as a whole, assuming it had been improved (Hdbk Utility, item A, Appendix B). The mean rating for this question was 4.8, with a SD of 1.6. This corresponds to a feeling that the handbook would be reasonably useful.

Assuming that a rating of 4.0 or less on the scale would indicate an attitude on the part of participants of positive handbook utility, one can ask what percentage of personnel expressing an opinion on this point (two did not respond) were positive? Fifteen of the 34 respondents or 44% rated handbook utility at 4.0 or less. Six of the 15 or 18% felt that the handbook would be very or extremely useful. The 44% who considered handbook utility to be moderately to extremely useful represented nine specialties (Human Factors, Maintainability, AGE, Operations Analysis, Reliability, Training, Miscellaneous and Design). It is interesting that only 2 of the 15 positive respondents represented general design engineering. This suggests that those who found the handbook most useful were those in highly specialized engineering areas that are more likely to require tradeoff analyses involving personnel. One might also suppose that those who had had experience with similar problems would have a more positive attitude toward the handbook as a whole. A Pearson r correlation between

ratings of Problem Fidelity and Handbook Utility responses resulted in a correlation of +.50, which is significant at the .01 level. There is thus a tendency, as one might expect, for those who have encountered similar problems to feel that the handbook would be useful.

Handbook Influence

Would such a handbook be influential in affecting system design (which is its ultimate purpose, of course)? Item B, Appendix B provides the relevant data. The mean rating was 4.0 with a SD of 1.3. This represents the feeling that such a handbook would be moderately influential. Twenty-two of the 34 respondents (62%) rated potential handbook influence as 4.0 or less (moderately influential). Ten of the respondents or 28% felt that such a handbook would be very or extremely influential (2.5 or less on the scale). The same engineering specialties that responded positively to Handbook Utility also responsed positively to this question, but here general design engineering was more heavily represented.

WHO ARE LIKELY TO BE HANDBOOK USERS

Because of large individual differences in the area of engineering specialization and years of experience, one would not expect every engineer to make use of the handbook. Since any handbook cannot appeal to everyone, one would wish to determine which engineering specialty the handbook appeals to most or with which it is most effective?

Since the handbook dealt with HR problems and its subject matter was oriented at least partially to maintenance themes, it would be interesting to contrast the responses of Human Factors (HF) and Maintainability (Maint.) engineers with those of other types. These and other comparisons can be seen in Table 5. In essence, all differences were non-significant. Consequently, significance levels have not been reported.

The small differences in performance either in solving the problems or in attitude toward HR data and handbook utility among participants of different specialty areas suggest that the prototype handbook appeals equally to all specialties.

Each of the rating items in the questionnaire was developed to elicit the participant's attitude toward the problems and the prototype handbook. Examination of the interrelationships among these ratings might therefore help to explain individual differences in problem solution and indicate most likely users of the prototype handbook. Using the Pearson r technique, all the major items in the questionnaire (with the exception of solution time which was considered to have only secondary significance) were intercorrelated. The results can be seen in the matrix in Table 6.

TABLE 5a. DIFFERENCES IN PARTICIPANT PERFORMANCE AS A FUNCTION OF SPECIALTY AREA

CORRECTNESS			TIME		
Measure	HF/Maint	Others	Measure	HF/Maint	Others
Mean %	61	71	Mean Time (Min.)	5.0	5.0
SD	17	14	SD	1.3	1.6
	HF	Maint.		HF	Maint.
Mean %	60	63	Mean Time (Min.)	4.9	5.2
SD	13	22	SD	1.4	0.6
	Maint.	Design Eng/ AGE/Avion		Maint.	Design Eng/ AGE/Avion
Mean %	63	68	Mean Time (Min.)	5.2	5.6
SD	22	18	SD	0.6	1.4
	Design Eng/ AGE/Avion	Others		Design Eng/ AGE/Avion	Others
Mean %	68	69	Mean Time (Min.)	5.6	6.4
SD	18	13	SD	1.4	1.4

TABLE 5b. DIFFERENCES IN PARTICIPANT ATTITUDE AS A FUNCTION OF SPECIALTY AREA

HR DATA UTILITY			OWN DATA UTILITY		
Measure	HF/Maint	Others	Measure	HF/Maint	Others
Mean Rating	3.6	3.4	Mean Rating	4.4	4.9
SD	1.0	1.0	SD	0.8	1.1

HANDBOOK UTILITY

Measure	HF/Maint	Others
Mean Rating	4.6	4.8
SD	1.7	1.6

TABLE 6. PEARSON PRODUCT-MOMENT CORRELATIONS AMONG QUESTIONNAIRE ITEMS

	Years of Experience	% Problems Correctly Solved	Solution Time	Problem Difficulty	Solution Certainty	Problem Fidelity	HR Data Utility	Own Data Utility	Own Data Accessibility	HDBK Utility	HDBK Influence	Use of HR Data
Years of Experience		.06	.02	-.07	-.14	-.03	-.14	-.14	-.28	.05	.09	-.16
% Problems Correctly Solved			.13	.00	.06	.03	.00	.41	.17	.03	.03	.12
Solution Time				.21	—	—	—	—	—	—	—	—
Problem Difficulty					.55	.01	.30	.20	-.05	.18	.09	.11
Solution Certainty						.26	.53	-.02	.12	.19	.16	.10
Problem Fidelity							.01	.29	.23	.50	.13	.27
HR Data Utility								-.19	-.25	.40	.45	-.08
Own Data Utility									.77	.00	-.35	.17
Own Data Accessibility										-.05	-.56	.15
Handbook Utility											.28	.34
Handbook Influence												.13
Use of HR Data												

When any sizeable number of correlations are run, it would be expected that a certain percentage of these would prove significant. In Table 6 $\underline{r}$ values of .30 or higher (which are significant at the .05 level) should be considered only as indicative and possibly worthy of further study.

Certain relationships seem logical. For example, it has already been mentioned that subjects who had encountered similar problems might well think better of the handbook (Problem Fidelity - Handbook Utility, +.50). Those who felt that HR data had utility would naturally feel that the handbook would have utility and be influential (HR Data Utility-Handbook Utility and Handbook Influence, +.40 and +.45). Own Data Utility and Own Data Accessibility would also be logically related (+.77). Those who thought better of their own data utility than of the handbook material would also downgrade Handbook Influence (-.35), although the relationship between Own Data Utility and Handbook Utility was exactly zero. Those who thought their own data were as accessible as the handbook material would probably be negative to Handbook Influence (-.56). Those who had used HR data in the past (item C, Appendix B) would be more likely to consider the handbook to have utility (+.34). Those who felt more certain about their solutions might also feel more positive about the usefulness of HR data (+.53). Problem difficulty and solution certainty should be related (+.55), but one would think it would be a negative relationship; probably there is a more important moderating factor that is not known. Problem difficulty is related to HR data utility, but the relationship is not strong (+.30). Correct solutions were related to a feeling of own data utility (+.41), but again the logic of the relationship is not apparent.

WHICH INDEXING SYSTEM IS PREFERABLE

The answer to this question requires (1) a comparison of Master Index (MI) responses (problems 1, 7) with Alphabetic Index (AI) responses (problems 8, 11) in terms of correctness and completion time; (2) analysis of the choices made by respondents when they had the opportunity to select between the two systems (problems 3 and 4); (3) analysis of their perception of the difficulty of using the two systems.

Statistics for correctness and time data are shown in Table 7.

It is obvious without the necessity of doing a formal statistical test that responses to MI problems differ markedly from those to AI problems. The question is whether this difference is significant. Because differences within MI and AI problems are practically non-existent (at least for correctness), responses for the two MI problems were combined as were those of the two AI problems. The t_{dep} value for combined correctness scores (1 & 7 vs 8 & 11) was 5.18 (34 df), significant at the 1% level, as was a comparable test solution time (t_{dep} = 8.01, 32 df). Objective performance scores therefore favor AI.

Of course, the problem situations with which the two types of index systems were compared may have differed significantly in terms of difficulty (apart from any difficulties in using the index). This turned out to be the case. Perceived difficulty of MI problems 1 and 7 was 2.9 and 5.0; of problems 8 and 11, 2.8 and 3.5. When the difficulty ratings given problems 1 and 7 (ratings of problem difficulty rather than difficulty in using the index) are compared with those of problems 8 and 11, t_{dep} is 3.26, which for 31 df is significant at the 1% level. The apparent superiority of the AI system must, therefore, be qualified by the greater easiness of the problems in which alphabetic indexing was required.

In two problems (3, 4) participants were asked to choose one of the two indexing schemes (the MI or the AI system) to find the correct table. The distribution of choices is shown in Table 8 and was tested using the Chi-square method (Siegel, 1956).

The participant was given four alternatives. He could have selected (and been satisfied with) MI or AI, or he could have selected MI or AI first and then have switched to the alternative indexing system if the first choice proved unsatisfactory. If those choices in which MI was selected first but then rejected (C) were added to the MI choices (A) and those in which AI was selected first but then rejected (D) were added to the AI choices (B), the disparity in favor of MI would be even more striking. It is apparent that engineers preferred the MI method, although they found difficulties in using it.

Participants were also asked to indicate how easy or difficult it was to use the MI and AI systems. The distribution of difficulty ratings for the two types of index systems is shown in Table 9.

TABLE 7. MI AND AI CORRECTNESS AND SOLUTION TIME

Measure	MI Problems 1	MI Problems 7	AI Problems 8	AI Problems 11
Mean Percent Correct	61	62	94	92
Mean Solution Time (Mins.)	5.3	4.3	2.8	4.3

TABLE 8. CHOICES BETWEEN MI AND AI SYSTEMS

Choice	Problem 3 Frequency	Problem 4 Frequency
A. MI	23	13
B. AI	3	5
C. MI first, then AI	2	9
D. AI first, then MI	2	1
	Chi-square = 42.79 df 3, p = .001	Chi-square = 11.4 df 3, p = .01

TABLE 9. PERCEIVED DIFFICULTY IN USING MI AND AI

Problems	MI 1	MI 7		AI 8	AI 11
Mean Rating	2.9	5.0		2.8	3.7
SD	1.4	1.8		1.2	1.5
t_{dep} 1, 7	8.08			2.95	
			t_{dep} (1, 7 vs 8, 11) = 3.12		
N	35			35	
Sig. Level	.01		.01	.01	

Obviously, use of the MI with problem 7 and AI with problem 11 resulted in somewhat greater perceived difficulty. Otherwise, subjects tended to view both MI and AI as being neither particularly easy nor difficult to use. To determine whether MI or AI presented greater difficulty to subjects, ratings of 1 and 7 combined and 8 and 11 combined were compared, using t_{dep}. This resulted in a value of 3.12 which was significant at the 1% level. Quite apart from the difficulty of the problems to which they are applied, the indexing methods are differentially difficult, the MI being perceived as significantly more difficult than the AI, even though respondents preferred to use MI when they had the opportunity. Of course, it is not completely possible to differentiate the inherent difficulty of an indexing system from the difficulty of the problem; a more difficult problem will demand more of an indexing system.

The difficulty involved in applying each of the three major MI steps was also explored. In each of the two MI problems (1, 7) subjects were asked to rate the difficulty of each step. The results are shown in Table 10.

TABLE 10. PERCEIVED DIFFICULTY OF MI STEPS

	Problem 1			Problem 7		
Steps	A	B	C	A	B	C
Mean Rating	2.8	2.9	3.0	4.5	4.6	4.2
SD	1.5	1.5	1.5	1.8	1.9	1.9

Step A - Determine section number from Master Index.

B - Find the appropriate index number from the Master Index Table of Contents.

C - Determine the table number from the Master Index Table of Contents.

The differences between steps <u>within</u> problems 1 and 7 are obviously miniscule, suggesting that all steps are equally easy or difficult. In problem 1 the ratings cluster between "easy" (2.5) and "neither easy nor difficult" (4.0). In problem 7, the ratings are on the difficult end of the continuum. Obviously there is a relationship between the difficulty of the problem and the difficulty in applying the index.

RECOMMENDATIONS FOR IMPROVEMENT

The recommendations to be described derive in many cases from the comments participants made. Question 3 in each data extraction problem provided a list of items (see Table 11) which personnel could check if they had difficulty with the problem. With 2988 possible items to be checked (36 participants x 14 items x 6 problems - 36)*, a total of 158 responses or 19% were made. Most comments were made in relation to problems 5 and 9, because these were perceived as most difficult. More important is the nature of the items checked. Item 2, not the kind of problem I am familiar with, was checked most often. The emphasis on problem familiarity is something we have encountered before. However, only 5 responses were made to item 5, problem not realistic. Apparently participants accepted the problems as realistic. (This point is important as tending to confirm the validity of the problem situations developed for the questionnaire.) Respondents felt that in some cases not enough data were available to solve the problem (item 4) and that the Implications of the data were not clearly pointed out (item 12). This is a common complaint encountered by many human factors engineers working in system development. There were some comments also on the difficulty of extracting data from handbook tables (item 7) and reluctance to use the handbook to solve the problems (item 8).

Tables 12 and 13 present recommendations made by participants for ways of using and improving the handbook. (Frequencies for individual items do not add up to 36 because many respondents failed to answer this question.) They saw a wide range of uses for the handbook, as evidenced by the distribution of comments. The handbook could be improved by making data more current and the indexing system easier to use. Observations of participant behavior (while they were completing the questionnaire) suggest that handbook acceptance would have been increased had both indexing systems been more efficient.

The following recommendations for improvement of the prototype handbook can be made on the basis of participant comments and observations by the investigator:

1. The categories in the MI (see Figure 3) appear to be too gross and should be made more detailed (perhaps by increasing the number of categories). The data parameters which engineers derive from their problems and with which

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*One item was inadvertently left out of problem 2.

TABLE 11. DISTRIBUTION OF PARTICIPANT COMMENTS ON PROBLEMS

	Problems 2	5	6	9	10	12	Total
1. Didn't understand problem.	2	1	1	5	0	0	9
2. Not the kind of problem I am familiar with.	8	9	3	6	1	2	29
3. Did not have enough time to solve.	0	1	0	0	0	0	1
4. Not enough data to solve problem.	3	1	4	13	0	3	24
5. Problem not realistic.	-*	0	1	3	1	0	5
6. Data irrelevant to problem.	0	0	3	4	0	0	7
7. Data difficult to extract from table.	1	4	3	4	1	3	16
8. Can't solve problem without handbook.	0	13	0	3	0	0	16
9. Information in table too verbal.	1	3	0	1	0	0	5
10. Data not current.	1	1	3	7	1	0	13
11. Organization of table confusing.	1	2	3	2	0	1	9
12. Implications of data not clearly pointed out.	4	8	2	7	0	3	24
13. Too much information in table.	0	0	0	0	0	0	0
14. Too much irrelevant information.	0	0	0	0	0	0	0
Total:	21	43	23	55	4	12	158

TABLE 12. DISTRIBUTION OF PARTICIPANT RECOMMENDATIONS FOR HANDBOOK USE

Use	Frequency
Avionics and fire control system historical data	10
Acquisition cost of avionics and fire control systems	7
Equipment design trade-off	19
Description of avionics/fire control tasks/jobs	8
Human error prediction	14
Manpower costs	15
Personnel selection criteria	7
Manpower skill and/or availability	11
Training costs and training time	18
Logistics costs and trade-off	15
Maintainability and maintenance performance times	20
Manpower life cycle costs	8
Prediction of technician performance	8
Fire control design characteristics	6

TABLE 13. DISTRIBUTION OF PARTICIPANT RECOMMENDATIONS FOR HANDBOOK IMPROVEMENT

Recommendation	Frequency
Improve overall handbook organization	5
Improve organization of individual tables	6
Make data more current	21
Increase amount of data in tables	9
Provide more data points	8
Reduce verbiage in tables	3
Present data in more quantitative form	6
Make index easier to use	19
Cover more subject areas	12
Reduce amount of material in tables	0
Indicate uses of data more effectively	8
Broaden data sources	6
Provide more graphic illustrations	8
Make instructions for indexing system clearer	11

they approach the MI are usually quite detailed and taken directly from the problem as they conceptualize it; e.g., "grade levels" (problem 5). If the term "grade level" or some category fairly close to it is not available in the MI, the engineer has difficulty finding the correct term, because now he must search for some more molar term which encompasses "grade level." The same comment might be made about the AI: the number of detailed categories, particularly those emphasizing interrelationships, should be much expanded.

2. The Implications section of the handbook tables is in most cases fairly abstract and non-communicative. To the engineer the term "implications" suggests that the category will explain the conclusions that should be drawn from the tabular or graphic material on the page. When the category does not provide this explanation, the engineer feels frustrated. It may be that the prototype handbook developers were overly conservative in what they felt they should say about their data. The Implications section of each table should point out the specific applications of the data and the conclusions that seem warranted from these data. Presently the Implications section is too narrowly related to fire control subsystem data. If the prototype handbook developers want to make the handbook more generally usable, generalizations that extend beyond the fire control subsystem data on which Implications is based should be indicated.

3. The section of the data tables dealing with Models for Data Application should be eliminated, at least until these models can in fact be applied to the data.

4. It has already been mentioned that engineers prefer their data to be as recent as possible. Limitations on data availability may make this difficult to accomplish, but the effort should be attempted. (See later comments on computerization.)

5. The explanation of the way in which the indexing systems should be used (which is included in the prototype handbook Introduction) and the way in which data should be extracted from tables (which is not fully explored in that Introduction) should be considerably amplified. It would be desirable to expand the handbook Introduction to include a number of sample problems which the user would work through to a specified correct answer, preferably in a programmed learning manner.

6. The kinds of problems for which the prototype handbook is most appropriate should be clearly spelled out, with illustrative situations. Some of the participants' initial uneasiness in using the handbook undoubtedly

resulted from their inability to conceptualize the uses to which the handbook data could be put. Examples of the kinds of problems for which data in the various handbook sections can supply solutions should be provided.

7. The handbook should be introduced to potential users with a tutorial group indoctrination session. This indoctrination will direct the user's attention to those handbook aspects he might otherwise miss on his own. Such indoctrination sessions introducing new material and concepts should be required in handbook development.

IV. DISCUSSION

This study began with a number of major questions: Can engineers use the handbook?; Will they use it?; Which of the various types of engineers are most likely to use the handbook? At the conclusion of the study the first two questions can be answered positively; as for the third question, the handbook appeals to all engineering specialties.

With regard to the question, "Can engineers use the handbook?" the fact that without substantial training to utilize the indexing systems and the tabular material, 68% of the problems presented were solved correctly, either wholly or partially, satisfies the criterion of effectiveness. Had participants been indoctrinated more fully on how to use the handbook to solve problems, this effectiveness measure would have been significantly higher. Moreover, participants performed significantly better on problems 5 and 9 with the handbook than without it and considered solution of problem 5 without the handbook to be significantly more difficult than solution of the same problem with the handbook. Their confidence in handbook solutions was rated significantly greater than their confidence in solutions without the handbook.

Objectively, therefore, what one can term the efficiency of the handbook, as defined by correct solutions, and its utility, as defined by participants' increased decision confidence and reduced problem difficulty, both favor the handbook.

But will engineers voluntarily use the handbook? This has always been the difficulty in the transmission of behavioral inputs to the engineer.

The answer to this question is reasonably positive. If engineers feel that a product will be useful, they will use it. Respondents felt that the handbook would be moderately to very useful in solving problems of the type the handbook did purport to solve. Forty-four percent of the participants felt that the handbook had positive utility and 62% felt that the handbook would influence their design. Although they felt that their own data sources were almost as good as those of the handbook, the former were less accessible.

With regard to the question, "Which of the various types of engineers represented in the sample of participants are most likely to use the prototype handbook?" the data are merely suggestive. Attempts to compare the performance of engineers in terms of their specialty areas elicited no significant differences which suggests that the handbook

appeals to all engineering types. Based on the ratings of handbook utility, there is some suggestion that engineers who perform in more specialized design efforts (e.g., Reliability, Maintainability, Training, etc.), are more likely to be positive toward handbook use then engineers in general design. This ties in also with the hypothesis (the most one can call it because it is based on a correlation of only +.50) that engineers who had encountered similar problems previously tended to be more positive toward the handbook than others.

The failure to discover distinctive user types in this evaluation may also mean that the target audience for this handbook is not to be found in the engineer's specialty area as much as it is in the type of job he does, a type of job that requires solution of problems for which handbook material is appropriate. It may be that the kinds of problems for which the prototype handbook is most adaptable are found mostly in analytic, planning and managerial positions within the Air Force and contractor facilities. The question of whether it is worthwhile on a life-cycle-personnel-cost basis to automate a new system is the sort of question asked very early in system development, at the stage at which analyses and planning must be performed, as in developing the Air Force's Operational Requirement or Required Operational Capability. Lower level system development personnel for whom behavioral data handbooks are usually written do not often deal with such problems.

If one were to sum up what this assessment reflects, it might be stated somewhat as follows: The prototype handbook is a useful tool and personnel using it can solve certain kinds of problems more effectively than they could otherwise. Because of this, it should be improved by updating its data and sharpening their implications, by simplifying the MI system and reducing unnecessary verbiage. To increase its utilization the introduction of the improved handbook should be preceded by a deliberate user indoctrination effort. In addition, a special effort should be made to identify the most promising target audience for this material. It must be recognized, as Reed et al. (1975) did, that all system development personnel do not have the same needs for behavioral data. Pinpointing the most receptive audience for the prototype handbook will increase its usefulness.

HR scientists who develop such handbooks must ultimately cope with the philosophical questions with which this report began:

1. Should HR data handbooks be geared for use directly by system development personnel without (or with only minimal assistance by) the behavioral specialist? Or should such handbooks be directed primarily at behavioral

specialists to assist them in making HR inputs to developers? The choice between these alternatives depends on whether one thinks the system developer has the necessary behavioral background to "go it on his own." It depends on whether the handbook developer can, on his own (i.e., without the participation of the human factors engineer in the development context), translate behavioral data into engineering equivalents that will satisfy his development needs.

The answers to the above questions have implications for the type of handbook developed and methods of assessing its usefulness. It is related also to the role one conceptualizes for the human factors engineer working in system development: whether he is to be the primary initiator of HR inputs to the engineer (in which case handbook material ought to be more directly aimed at him) or more passive relative to the engineer.

The answers to these questions are not of course completely dichotomous, because emphasizing one approach does not require rejecting the other completely. Whatever the answer, however, consideration of these questions is required because it is likely that many HR data handbooks are developed in ignorance of the real contexts in which these handbooks will be used--or not used. For this reason research into handbook methodology--the kinds of problems faced by system development personnel and the data they need, the ways they have of using behavioral inputs--is a necessary precursor of effective handbook development.

2. Should the handbook developer conceptualize the target audience for HR data handbooks as very broad (e.g. specialists such as training personnel, human factors, reliability and maintainability engineers and general design engineers) or should one attempt to find a more restricted specialist audience? The broader the audience the more difficult it is to satisfy any segment of that audience. A very "narrow" audience may be thought, however, to lack cost-effectiveness; some may feel that handbooks are profitable only when they have broad appeal. But is it possible to appeal to a mass audience if differences among engineers in background and what they do are so large?

3. Should one approach the compilation of behavioral data by attempting to find whatever data are available and assembling them; or should one start first by determining the kinds of problems for which data are needed and then assembling only data relevant to selected problems? The general scarcity of behavioral data has probably led to a concentration on the first approach, although it would be wrong to assume that handbook developers have wholly ignored the problems for which data are needed.

Despite the difficulty of the questions posed above, it is obvious that there will be continuing attempts to develop behavioral data handbooks. And logically so, since not even an "expert" in the behavioral sciences has all the information he needs when he needs it.

Human factors research is performed in order to provide data that will help solve difficult system development problems. In order to make that research meaningful, its results must be communicated to a user, whoever that user is. Communication to anyone other than the very highly specialized researchers who perform this research demands a vehicle, which is the handbook. Indeed, some human factors engineers feel that there is no economic justification to support human factors research for which results cannot be communicated in handbook form.

From that standpoint, one of the major functions the behavioral scientist must perform is the communication of his research findings in the form of handbooks. Technical reports and scientific journals do not satisfy the informational needs of system developers, because they have no time to find them and even specialists have difficulty assembling these materials.

In this connection consideration should be given to the use of computerized information-retrieval systems for the provision of HR data. Since HR data tend to decay rapidly, computer-based systems may be more efficient in updating data than hardcopy volumes. The cost involved for the former, while high, is not significantly greater than that of compiling data for handbooks, since the underlying preparatory work is the same in either case. The same factors that apply to handbook development must also be considered in computerized data systems.

Since technical reports and scientific journals are concerned largely with research and not the application of research findings, the handbook or its computerized equivalent must be the means of translating behavioral data into system development terms. Even more than communication, the translation function provides an even more important rationale for the handbook.

For HR data, which are much more difficult to handle than more molecular human engineering data, the handbook is even more a necessity. The prototype handbook whose assessment is discussed in this report is an excellent start in that direction.

V. CONCLUSIONS AND RECOMMENDATIONS

The following conclusions are derived:

1. System development personnel can utilize the prototype handbook to make significantly more correct decisions than without the handbook. This is evidenced by the fact that they solved 68% of the problems presented and performed significantly more effectively with the handbook as an aid than without it. With the handbook, engineers had greater confidence in their decisions and felt that the problems were less difficult to solve.

2. Based on the assumption that those who see utility in a product will use it, it can be expected that a very substantial number of engineers will use the handbook. Forty-four percent of participants saw the handbook as having utility; 62% believed it would influence design. Moreover, although they considered their own data sources as good as the handbook, the former were much less accessible.

3. Those who see utility in the handbook are more likely to have specialized jobs (e.g., Human Factors, Maintainability, Crew Station Design) than general design functions. Based on a correlation of +.50 between Problem Fidelity and Handbook Utility, it appears that those who have used handbooks to solve trade-off problems are more positive to the handbook.

4. Engineers preferred to use the Master Index system rather than the Alphabetical Index, but experienced greater difficulty with the former. They performed more effectively with the Alphabetical Index, presumably because they were more familiar with it.

5. A number of improvements were recommended by participants, including updating data, simplifying the Master Index system, reducing verbiage in the tables and clarifying the implications of handbook data.

The following recommendations are made:

1. The results of this assessment study are sufficiently encouraging to warrant continuing the effort to develop HR data handbooks.

2. The development of a full-scale handbook should consider the following:

   a. The MI system should be revised to expand its categories and to make them more detailed.

b. The Implications section of the data tables should be written in more detailed fashion, explicitly specifying the design conclusions that may be derived from the data.

c. The Introduction should be considerably expanded to make it an aid in teaching the use of the handbook. The Introduction should include a listing of the types of system development problems for which the handbook is most useful and a number of sample problems that can be worked through by the user on a step-by-step basis to a specified answer.

d. The data contents should be updated as much as possible.

e. The material in Section III of the prototype handbook that deals with parameters that cut across the individual fire control subsystems and apply to systems in general should be expanded. This will increase the utility of the handbook.

3. The assessment presented in this report was limited to the concept and structure of a HR handbook. Assessment of a full-scale handbook should be conducted during the development of the handbook and should emphasize the validity of the data contents.

4. In line with concepts described in the Discussion section, consideration should be given to supporting research designed to discover the most effective target audience for HR material. The handbook development process should be considered as much more than mere compilation of data. This requires research to determine the target audience before the handbook is developed and determination of that audience's needs and characteristics. Consideration should also be given to the development of HR handbooks that deal with operator/maintainer behavior in relation to generalized equipment parameters that cut across specific subsystems.

5. A study should be performed to investigate the feasibility of using computerized information-retrieval techniques to substitute for hardcopy handbooks. A hybrid system involving the use of a computer to prepare periodically updated hardcopy handbooks should be investigated.

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APPENDIX A

THE PROTOTYPE HANDBOOK QUESTIONNAIRE

Problem 1 Start Time __________

In field shop repair of fire control systems, what is the relationship between occupational job/duty and performing skill level? Using the Master Index, find the number of the table describing this relationship.

ANSWER: Table ____________

In the questions below check anywhere along the scale.

1. How easy or difficult was the problem to solve?

Very Easy	Easy	Neither Easy Nor Difficult	Difficult	Very Difficult

2. How easy was it to use the Master Index in finding the correct table?

Very Easy	Easy	Neither Easy Nor Difficult	Difficult	Very Difficult

3. With what word or words did you enter the Index first?______

____

If you used additional terms, what were they?______________

____

4. How easy was it to perform the individual steps of the Master Index procedure?

A. To determine section number from Master Index:

Very Easy	Easy	Neither Easy Nor Difficult	Difficult	Very Difficult

B. To find the appropriate index number from the Master Index Table of Contents?

Very Easy	Easy	Neither Easy Nor Difficult	Difficult	Very Difficult

C. To determine the table number from the Master Index Table of Contents?

Very Easy	Easy	Neither Easy Nor Difficult	Difficult	Very Difficult

5. If you found any of the preceding steps in the Master Index procedure difficult to perform, was it because of difficulty in (check one or more below):

_____A. Translating problem parameters into Index search terms.

_____B. Overall organization of the Master Index.

_____C. Format of the Master Index Table of Contents.

_____D. Finding the correct search term in the left hand margin of the Master Index.

_____E. Understanding the relationship within the Master Index Table of Contents.

_____F. Finding the correct table number in the Master Index Table of Contents.

COMMENTS:____

____

Stop Time _________

Problem 2 Start Time __________

As a member of the Reliability Analysis Group, you must estimate the availability of a new fire control system radar transmitter now under development. Since availability is determined by (among other factors) unscheduled organizational (troubleshooting) time, you must include troubleshooting time in your calculations. However, no data on the new transmitter are available. You therefore attempt to predict this troubleshooting time on the basis of troubleshooting data for previous transmitters, since the new transmitter is not substantially advanced over those of the present generation (FB111A, A-7D). What would you estimate as average troubleshooting time for the new transmitter?

The data relevant to this problem can be found in Table I.30-9.17.

ANSWER: ____________

1. How easy or difficult was this problem to solve?

Very Easy	Easy	Neither Easy Nor Difficult	Difficult	Very Difficult

2. How certain are you about the correctness of your answer?

Completely Certain	Very Certain	Neither Very Certain nor Very Uncertain	Very Uncertain	Completely Uncertain

3. If this problem was difficult to solve or you are uncertain about the answer, indicate why by checking one or more of the following and explain under COMMENTS:

____A. Didn't understand problem.

____B. Not the kind of problem I am familiar with.

____C. Did not have enough time to solve.

____D. Not enough data in table to solve problem.

____E. Data in table was irrelevant to problem.

____F. Data difficult to extract from table.

____G. Information in table too verbal.

____H. Data not current.

3. (continued)

____I. Organization of table confusing.

____J. Implications of data in table not clearly pointed out.

____K. Too much information presented in table.

____L. Too much irrelevant information in table.

4. In your work have you encountered problems similar to the one you have just solved?

Constantly	Very Often	Sometimes	Rarely	Never

5. If in your work you encountered a problem similar to the one you have just solved, would the material in the tables have been useful in solving that problem?

Extremely	Very Useful	Moderately Useful	Slightly Useful	No Use At All

6. What information do you currently use to solve such a problem? Check one or more:

____A. Information is unavailable.

____B. Government reports.

____C. Company historical data.

____D. Logic.

____E. Textbooks.

____F. Other (describe)____

7. For this problem how useful would your own data sources be compared to the handbook?

Much More Useful	More Useful	Just as Useful	Slightly Useful	Much Less Useful

8. For this problem how <u>accessible</u> would your <u>own data sources</u> be compared to the handbook?

Much More Accessible	More Accessible	Equally Accessible	Less Accessible	Much Less Accessible

COMMENTS: ____

____

____

Stop Time __________

Problem 3 Start Time ________

What is the relationship between 3ABR32331 training time on fire control indicator scopes and skill level 3? Find the number of the table describing this relationship by using either the Master Index or the Alphabetical Index.

ANSWER: Table ________

1. How easy or difficult was this problem to solve?

Very Easy	Easy	Neither Easy Nor Difficult	Difficult	Very Difficult

2. Which indexing system did you use to find the table?

____A. Master Index

____B. Alphabetical Index.

____C. Tried Master Index first, then Alphabetical Index.

____D. Tried Alphabetical Index first, then Master Index.

3. Why did you select the index you used?

A. ________________ is faster.

B. ________________ is easier.

C. ________________ leads more directly to correct table.

D. Other (describe) ________________________________

4. With what word or words did you enter the index first? ____

____

If you used additional terms, what were they? ____________

____

COMMENTS: ____

____

____

Stop Time ________

Problem 4 Start Time ________

The question of the availability in the 1980's of 3, 5, 7 and 9 skill levels for career fields 321XX through 326XX arises. Use either the Master Index or the Alphabetical Index to find the table that will provide the needed data.

ANSWER: Table ________

1. How easy or difficult was this problem to solve?

Very Easy	Easy	Neither Easy Nor Difficult	Difficult	Very Difficult

2. Which indexing system did you use to find the table?

____A. Master Index.

____B. Alphabetical Index

____C. Tried Master Index first, then Alphabetical Index.

____D. Tried Alphabetical Index first, then Master Index.

3. Why did you select the index you used?

A. ____________________ is faster.

B. ____________________ is easier.

C. ____________________ leads more directly to correct table.

D. Other (describe) ____________________________________

4. With what word or words did you enter the index first? ____

____

If you used additional terms, what were they? ____________

____

COMMENTS: ____

____

____

Stop Time ________

Problem 5 **Start Time** _________

DO NOT USE YOUR HANDBOOK TO SOLVE THIS PART OF THE PROBLEM

You are part of a project team developing policies for training, promotion and retention of enlisted technicians. Your specific responsibility is avionics personnel. Assuming that future requirements for and availability of avionics maintenance manpower will be the same as those of the current period (circa 1970), in what grade levels (E-4 through E-9) will there be shortages?

ANSWER: Check one or more below:

E-4 **E-5** **E-6** **E-7** **E-8** **E-9**

1. How easy or difficult was this problem to solve?

Very Easy	Easy	Neither Easy Nor Difficult	Difficult	Very Difficult

2. How certain are you about the correctness of your answer?

Completely Certain	Very Certain	Neither Very Certain nor Very Uncertain	Very Uncertain	Completely Uncertain

Problem 5 (continued)

Now open your handbook to Table II.2-31.1 which contains data relevant to this problem. Analyze the table to confirm your previous answer or to find a better one. If you should change your mind about that previous answer, do not revise it.

ANSWER: Check one or more below:

E-4 E-5 E-6 E-7 E-8 E-9

1. How easy or difficult was this problem to solve with the handbook?

Very Easy	Easy	Neither Easy Nor Difficult	Difficult	Very Difficult

2. How certain are you now about the correctness of your answer?

Completely Certain	Very Certain	Neither Very Certain nor Very Uncertain	Very Uncertain	Completely Uncertain

3. If this problem was difficult to solve or you are uncertain about the answer, indicate why by checking one or more of the following and explain under COMMENTS:

____A. Didn't understand problem.

____B. Not the kind of problem I am familiar with.

____C. Did not have enough time to solve.

____D. Not enough data in table to solve problem.

____E. Problem not realistic.

____F. Data in table was irrelevant to problem.

____G. Data difficult to extract from table.

____H. Can't solve problem without handbook.

____I. Information in table too verbal.

____J. Data not current.

____K. Organization of table confusing.

3. (continued)

____L. Implications of data in table not clearly pointed out.

____M. Too much information presented in table.

____N. Too much irrelevant information in table.

____O. Other (describe) ______________________________

4. In your work have you encountered problems similar to the one you have just solved?

Constantly	Very Often	Sometimes	Rarely	Never

5. If in your work you encountered a problem similar to the one you have just solved, would the material in the tables have been useful in solving that problem?

Extremely Useful	Very Useful	Moderately Useful	Slightly Useful	No Use At All

6. What information do you currently use to solve such a problem? Check one or more:

____A. Information is unavailable.

____B. Government reports.

____C. Company historical data.

____D. Logic.

____E. Textbooks.

____F. Other (describe) ______________________________

7. For this problem how useful would your own data sources be compared to the handbook?

Much More Useful	More Useful	Just as Useful	Less Useful	Much Less Useful

8. For this problem how <u>accessible</u> would your <u>own data sources</u> be compared to the handbook?

Much More Accessible	More Accessible	Equally Accessible	Less Accessible	Much Less Accessible

COMMENTS: ____

____

____

Stop Time __________

Problem 6 Start Time ________

The X________ company is bidding on the development of a new generation fire control radar subsystem. To determine total development cost you must predict training time for level 3 mechanics on the new system. There may be a relationship between the cost of developing the system and training time, so you need data relating training time to acquisition cost. However, all you have is a best estimate of the subsystem cost, $225,000. If the relationship between cost and training time is correct, how long should training time (in weeks) be?

The data relevant to this problem can be found in Table I.19-3.1.

ANSWER: ____________________

1. How easy or difficult was this problem to solve?

Very Easy	Easy	Neither Easy Nor Difficult	Difficult	Very Difficult

2. How certain are you about the correctness of your answer?

Completely Certain	Very Certain	Neither Very Certain nor Very Uncertain	Very Uncertain	Completely Uncertain

3. If this problem was difficult to solve or you are uncertain about the answer, indicate why by checking any or all of the following and explain under COMMENTS:

____A. Didn't understand problem.

____B. Not the kind of problem I am familiar with.

____C. Did not have enough time to solve.

____D. Not enough data in table to solve problem.

____E. Problem not realistic.

____F. Data in table was irrelevant to problem.

____G. Data difficult to extract from table.

____H. Information in table too verbal.

____I. Data not current.

3. (continued)

____J. Organization of table confusing.

____K. Implications of data in table not clearly pointed out.

____L. Too much information presented in table.

____M. Too much irrelevant information in table.

____N. Other (describe)________________________________

4. In your work have you encountered problems similar to the one you have just solved?

Constantly	Very Often	Sometimes	Rarely	Never

5. If in your work you encountered a problem similar to the one you have just solved, would the material in the tables have been useful in solving that problem?

Extremely Useful	Very Useful	Moderately Useful	Slightly Useful	No Use At All

6. What information do you currently use to solve such a problem? Check one or more:

____A. Information is unavailable.

____B. Government reports.

____C. Company historical data.

____D. Logic.

____E. Textbooks.

____F. Other (describe)________________________________

7. For this problem how <u>useful</u> would your <u>own data sources</u> be compared to the handbook?

Much More Useful	More Useful	Just as Useful	Less Useful	Much Less Useful

8. For this problem how accessible would your own data sources be compared to the handbook?

Much More Accessible	More Accessible	Equally Accessible	Less Accessible	Much Less Accessible

COMMENTS: ______________________________

____

____

Stop Time __________

Problem 7 Start Time ________

In the process of developing a new generation fire control system you are required to predict the percent of time that will be spent by 3, 5 and 7 skill level maintenance men performing general electronic maintenance and repair jobs on the new system. Find the number of the table providing these data by using the Master Index.

ANSWER: Table ________

1. How easy or difficult was the problem to solve?

Very Easy	Easy	Neither Easy Nor Difficult	Difficult	Very Difficult

2. How easy was it to use the Master Index in finding the correct table?

Very Easy	Easy	Neither Easy Nor Difficult	Difficult	Very Difficult

3. With what word or words did you enter the Index first? ________

____

If you used additional terms, what were they? ________

____

4. How easy was it to perform the individual steps of the Master Index procedure?

A. To determine section number from Master Index:

Very Easy	Easy	Neither Easy Nor Difficult	Difficult	Very Difficult

B. To find the appropriate index number from the Master Index Table of Contents?

Very Easy	Easy	Neither Easy Nor Difficult	Difficult	Very Difficult

4. (continued)

C. To determine the table number from the Master Index Table of Contents?

Very Easy	Easy	Neither Easy Nor Difficult	Difficult	Very Difficult

5. If you found any of the preceding steps in the Master Index procedure difficult to perform, was it because of difficulty in (check one or more below):

____A. Translating problem parameters into Index search items.

____B. Overall organization of the Master Index.

____C. Format of the Master Index Table of Contents.

____D. Finding the correct search term in the left hand margin of the Master Index.

____E. Understanding the relationship within the Master Index Table of Contents.

____F. Finding the correct table number in the Master Index Table of Contents.

COMMENTS: ____

____

____

Stop Time __________

Problem 8 Start Time __________

What is the relationship between radar subsystems logistics support costs and unscheduled maintenance manhours? Find the number of the table describing this relationship by using the Alphabetical Index.

ANSWER: Table ________

1. How easy or difficult was the problem to solve?

Very Easy	Easy	Neither Easy Nor Difficult	Difficult	Very Difficult

2. How easy was it to use the Alphabetical Index to find the correct table?

Very Easy	Easy	Neither Easy Nor Difficult	Difficult	Very Difficult

3. With what word or words did you enter the Index first? ______

____

If you used additional terms, what were they? ______________

____

4. If you found the Alphabetical Index difficult to use, was it because (check one or more):

____A. The listings are incomplete.

____B. The listings are not logically arranged.

____C. The listings are not sufficiently detailed.

____D. Too much cross-referencing required to find correct listing.

____E. Other (describe fully). ______________________________

____

COMMENTS: ____

____

____

Stop Time __________

Problem 9 Start Time __________

DO NOT USE YOUR HANDBOOK TO SOLVE THIS PROBLEM

In developing future manpower cost projections for the Air Force, it is necessary to predict the cost of training a man in system maintenance of fire control systems (3ABR32331). The cost per student for this type of training from 1959 to 1968 (latest data available) averaged $8,191. Assuming no significant changes from 1968 costs, what do you estimate the cost will be in 1982?

ANSWER: ____________________

1. How easy or difficult was this problem to solve?

Very Easy	Easy	Neither Easy Nor Difficult	Difficult	Very Difficult

2. How certain are you about the correctness of your answer?

Completely Certain	Very Certain	Neither Very Certain nor Very Uncertain	Very Uncertain	Completely Uncertain

Problem 9 (continued)

Now open your handbook to Table I.22-2.1 which contains data relevant to this problem. Analyze the table to confirm your previous answer or to secure a new one. If you should change your mind about that previous answer, do not revise it.

ANSWER: ____________________

1. How easy or difficult was this problem to solve with the handbook?

Very Easy	Easy	Neither Easy Nor Difficult	Difficult	Very Difficult

2. How certain are you now about the correctness of your answer?

Completely Certain	Very Certain	Neither Very Certain nor Very Uncertain	Very Uncertain	Completely Uncertain

3. If this problem was difficult to solve or you are uncertain about the answer, indicate why by checking one or more of the following and explain under COMMENTS:

____A. Didn't understand problem.

____B. Not the kind of problem I am familiar with.

____C. Did not have enough time to solve.

____D. Not enough data in table to solve problem.

____E. Problem not realistic.

____F. Data in table was irrelevant to problem.

____G. Data difficult to extract from table.

____H. Can't solve problem without handbook.

____I. Information in table too verbal.

____J. Data not current.

____K. Organization of table confusing.

____L. Implications of data in table not clearly pointed out.

____M. Too much information presented in table.

3. (continued)

____N. Too much irrelevant information in table.

____O. Other (describe) ______________________________

4. In your work have you encountered problems similar to the one you have just solved?

Constantly	Very Often	Sometimes	Rarely	Never

5. If in your work you encountered a problem similar to the one you have just solved, would the material in the tables have been useful in solving that problem.

Extremely Useful	Very Useful	Moderately Useful	Slightly Useful	No Use At All

6. What information do you currently use to solve such problems? Check one or more:

____A. Information is unavailable.

____B. Government reports.

____C. Company historical data.

____D. Logic.

____E. Textbooks.

____F. Other (describe) ______________________________

7. For this problem how <u>useful</u> would your <u>own data sources</u> be compared to the handbook?

Much More Useful	More Useful	Just as Useful	Less Useful	Much Less Useful

8. For this problem how <u>accessible</u> would your <u>own data sources</u> be compared to the handbook?

Much More Accessible	More Accessible	Equally Accessible	Less Accessible	Much Less Accessible

Problem 9 (continued)

COMMENTS: ____

____

____

Stop Time ________

Problem 10 Start Time __________

The Air Force has specified that maximum unit replacement time for a new avionics system under development cannot exceed 6 hours. Your task is to predict actual replacement time. It is a reasonable hypothesis that maintenance time is at least partially determined by hardware design characteristics, in this case the number of components that must be manipulated. The new system is composed of 30 major parts that must be handled in order to repair it. Estimate the unit replacement time for this system and, if it exceeds Air Force requirements, the number of components that will have to be eliminated.

The data relevant to this problem can be found in Table III.5-36.5.

ANSWER: ______________________________

1. How easy or difficult was this problem to solve?

Very Easy	Easy	Neither Easy Nor Difficult	Difficult	Very Difficult

2. How certain are you about the correctness of your answer?

Completely Certain	Very Certain	Neither Very Certain nor Very Uncertain	Very Uncertain	Completely Uncertain

3. If this problem was difficult to solve or you are uncertain about the answer, indicate why by checking one or more of the following and explain under COMMENTS:

____A. Didn't understand problem.

____B. Not the kind of problem I am familiar with.

____C. Did not have enough time to solve.

____D. Not enough data in table to solve problem.

____E. Problem not realistic.

____F. Data in table was irrelevant to problem.

____G. Data difficult to extract from table.

____H. Information in table too verbal.

____I. Data not current.

3. (continued)

____J. Organization of table confusing.

____K. Implications of data in table not clearly pointed out.

____L. Too much information presented in table.

____M. Too much irrelevant information in table.

____N. Other (describe)____

4. In your work have you encountered problems similar to the one you have just solved?

Constantly	Very Often	Sometimes	Rarely	Never

5. If in your work you encountered a problem similar to the one you have just solved, would the material in the tables have been useful in solving that problem?

Extremely Useful	Very Useful	Moderately Useful	Slightly Useful	No Use At All

6. What information do you currently use to solve such problems? Check one or more:

____A. Information is unavailable.

____B. Government reports.

____C. Company historical data.

____D. Logic.

____E. Textbooks.

____F. Other (describe)____

7. For this problem how <u>useful</u> would your <u>own data sources</u> be compared to the handbook?

Much More Useful	More Useful	Just as Useful	Less Useful	Much Less Useful

8. For this problem how accessible would your own data sources be compared to the handbook?

Much More Accessible	More Accessible	Equally Accessible	Less Accessible	Much Less Accessible

COMMENTS: ____

____

____

Stop Time __________

Problem 11 Start Time __________

During the development of a new generation avionics system you must decide between two designs that differ in their hardware characteristics. Since one system requires more steps in functional checkout than the other, this may create more errors in the technician's performance. Find the table that relates number of steps in functional checkout to number of errors. Use the Alphabetical Index for this purpose.

ANSWER: Table __________

1. How easy or difficult was the problem to solve?

Very Easy	Easy	Neither Easy Nor Difficult	Difficult	Very Difficult

2. How easy was it to use the Alphabetical Index to find the correct table?

Very Easy	Easy	Neither Easy Nor Difficult	Difficult	Very Difficult

3. With what word or words did you enter the Index first? ______

____

If you used additional terms, what were they? ______________

____

4. If you found the Alphabetical Index difficult to use, was it because (check one or more):

____A. The listings are incomplete.

____B. The listings are not logically arranged.

____C. The listings are not sufficiently detailed.

____D. Too much cross-referencing required to find correct listing.

____E. Other (describe fully) ______________________

____

COMMENTS: ______________________________

____

____

Stop Time __________

Problem 12 Start Time ________

In planning the integrated logistics system for a new fire control radar subsystem you must estimate the number of maintenance manhours (MMH) per 1000 flight hours (FH). Recent data suggest that there is a relationship between number of MMH and number of line replaceable units (LRUs). The new subsystem will contain 12 LRUs. What is your estimate of the expected MMH/1000FH (unscheduled organizational maintenance)?

The data relevant to this problem can be found in Table I.11-4.1.

ANSWER: ____________________

1. How easy or difficult was this problem to solve?

Very Easy	Easy	Neither Easy Nor Difficult	Difficult	Very Difficult

2. How certain are you about the correctness of your answer?

Completely Certain	Very Certain	Neither Very Certain nor Very Uncertain	Very Uncertain	Completely Uncertain

3. If this problem was difficult to solve or you are uncertain about the answer, indicate why by checking one or more of the following and explain under COMMENTS:

____A. Didn't understand problem.

____B. Not the kind of problem I am familiar with.

____C. Did not have enough time to solve.

____D. Not enough data in table to solve problem.

____E. Problem not realistic.

____F. Data in table was irrelevant to problem.

____G. Data difficult to extract from table.

____H. Information in table too verbal.

____I. Data not current.

____J. Organization of table confusing.

3. (continued).

____K. Implications of data in table not clearly pointed out.

____L. Too much information presented in table.

____M. Too much irrelevant information in table.

____N. Other (describe) ____________________________________

4. In your work have you encountered problems similar to the one you have just solved?

Constantly	Very Often	Sometimes	Rarely	Never

5. If in your work you encountered a program similar to the one you have just solved, would the material in the tables have been useful in solving that problem?

Extremely Useful	Very Useful	Moderately Useful	Slightly Useful	No Use At All

6. What information do you currently use to solve such problems? Check one or more:

____A. Information is unavailable.

____B. Government reports.

____C. Company historical data.

____D. Logic.

____E. Textbooks.

____F. Other (describe) ____________________________________

7. For this problem how useful would your own data sources be compared to the handbook?

Much More Useful	More Useful	Just as Useful	Less Useful	Much Less Useful

8. For this problem how accessible would your own data sources be compared to the handbook?

Much More Accessible	More Accessible	Equally Accessible	Less Accessible	Much Less Accessible

COMMENTS:______________________________

Stop Time ________

THE FOLLOWING QUESTIONS RELATE TO YOUR OPINION OF THE HANDBOOK AS A WHOLE where the question is a rating scale, mark anywhere along the scale.

1. How useful were the individual sections of the tables in solving the previous problems?

Section	Extremely Useful	Very Useful	Moderately Useful	Slightly Useful	Not Useful At All
Graph or Histogram					
Table					
Title					
Comments					
Implications					
Data Sources					
Models for Data Application					
Subject					
Index/ Cross-Index	Extremely Useful	Very Useful	Moderately Useful	Slightly Useful	Not Useful At All

COMMENTS: ______________________________

____

____

2. Did the tables provide as much data as you would want in a handbook of this type?

Much More than Desirable	More than Enough	Just Enough	Not as Much as it Should	Seriously Lacking

3. If the tables did not contain enough data, how much more data and of what type would you want? ______________________________

____

____

4. How useful would an improved version of this type of handbook be in the work you do?

Extremely Useful	Very Useful	Moderately Useful	Slightly Useful	Not Useful At All

5. For which of the following types of problems could such a handbook be used effectively? Check one or more and rank those you check.

____Avionics and fire control system historical data.

____Acquisition cost of avionics and fire control systems.

____Equipment design tradeoffs.

____Description of avionics/fire control tasks/jobs.

____Human error prediction.

____Manpower costs.

____Personnel selection criteria.

____Manpower skill and/or availability.

____Training costs and training time.

____Logistics costs and tradeoffs.

____Maintainability and maintenance performance times.

____Manpower life cycle costs.

____Prediction of technician performance.

____Fire control design characteristics.

6. Assume that you had to solve the kinds of problems described in the immediately previous question, how influential would an improved handbook of this type be in affecting your system design decisions?

Extremely Influential	Very Influential	Moderately Influential	Slightly Influential	No Influence At All

7. What would you recommend to improve the handbook? Check one or more of the following and rank those you check.

____Improve overall handbook organization.

____Improve organization of individual tables.

____Make data more current.

____Increase amount of data in tables.

____Provide more data points.

____Reduce verbiage in tables.

____Present data in more quantitative form.

____Make index easier to use.

____Cover more subject areas.

____Reduce amount of material in tables.

____Indicate uses of data more effectively.

____Broaden data sources.

____Provide more graphic illustrations.

____Make instructions for indexing system clearer.

8. How often have you used human resources data in your work? Remember that human resources data are data relating to personnel availability, training, use, cost, etc.

Constantly	Often	Sometimes	Rarely	Never

9. If you have used such data

A. What type? ____________________

B. Where did you get it? ____________________

C. For what types of problems? (Use list in question 5 as guide) ____________________

____

D. How useful did you find these data?

Extremely Useful	Very Useful	Moderately Useful	Slightly Useful	Not Useful At All

10. How important do you consider human resources and human factors in operation and maintenance of avionics and fire control equipment?

More Important than Anything Else	More Important than Physical (Engineering) Factors	As Important as Physical Factors	Less Important than Physical Factors	Completely Unimportant

11. How important do you consider human resources data in affecting system design?

Overwhelmingly Important	More Important than Other Data	As Important as Any Other Data	Less Important than Other Data	Completely Unimportant

AD-A039 269 MANNED SYSTEMS SCIENCES INC WESTLAKE VILLAGE CALIF F/G 5/9
ASSESSMENT OF A PROTOTYPE HUMAN RESOURCES DATA HANDBOOK FOR SYS--ETC(U)
DEC 76 D MEISTER F33615-76-C-0045
UNCLASSIFIED AFHRL-TR-76-92 NL

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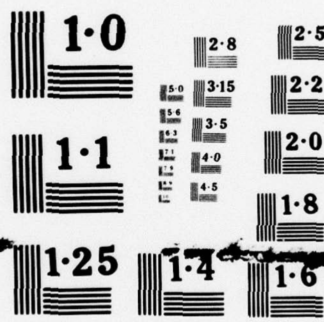

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MICROCOPY RESOLUTION TEST CHART

INTRODUCTION TO APPENDICES B AND C

The data items listed in these appendices are defined as follows:

Specialty: Participant's background.

Years of experience: Years worked in specialty.

% problems correctly solved: Mean percentage of the 12 problems correctly solved.

Solution time: Time taken by participant to solve problem.

The following items are rating measures:

Problem difficulty: Rating of problem difficulty.

Solution certainty: Rating of participant's confidence in the correctness of his problem solution.

Problem fidelity: Rating of the similarity of questionnaire problems to those the participant deals with ordinarily.

HR data utility: Rating of prototype handbook usefulness in solving the problem.

Own data utility: Rating of the usefulness of participant's own data sources compared with the prototype handbook.

Own data accessibility: Rating of the accessibility of the participant's own data sources compared with that of the prototype handbook.

Hdbk utility: Rating of the utility of an improved version of the prototype handbook.

Hdbk influence: Rating of the influence an improved prototype handbook would have on system design.

Use of HR data: Rating of how often the participant has used HR data in his work.

HR importance: Rating of the importance of HR and HR data in system design.

Data solution times and questions 1 through 8 represent the mean and standard deviation (SD) of each participant's

responses over the 12 problems. Since items A-D were presented only once (at the conclusion of the questionnaire) only the single response is presented. Although data for solution times are expressed in tenths of minutes, this results simply from averaging the time data; actual times were reported by participants only to the nearest minute. Blanks in Appendix B result from individual failures to respond to a particular question. The original computations were carried out to two decimal places, but for simplicity the data in these appendices have been rounded off to one digit.

APPENDIX B

PARTICIPANT RESPONSES TO THE QUESTIONNAIRE

Data Category	Participants			
Specialty	1 Maint.	2 Design	3 Avion.	4 Avion.
Years of Experience	3	-	18	8
% Problems Correctly Solved	.80	.71	.50	.92
Solution Time (Min.)	*6.0/4.9	4.6/3.7	5.7/3.4	6.9/4.3
Problem Difficulty (q. 1)	2.7/1.5	3.2/1.8	3.6/1.4	3.7/2.2
Solution Certainty (q. 2)	3.4/1.8	3.7/2.2	4.0/0.8	1.7/1.5
Problem Fidelity (q. 4)	6.0/1.5	3.7/1.1	4.0/0.9	7.0/0.0
HR Data Utility (q. 5)	1.7/0.8	3.0/1.2	3.5/1.2	-
Own Data Utility (q. 7)	5.0/1.7	4.0/0.0	3.5/0.8	-
Own Data Accessibility (q. 8)	5.5/0.0	5.2/0.7	4.2/1.8	-
(A) Hdbk Utility	4.0	2.5	4.0	7.0
(B) Hdbk Influence	4.0	2.5	5.5	4.0
(C) Use of HR Data	5.5	4.0	5.5	5.5
(D) HR Importance	4.0	4.0	4.7	4.0
Specialty	5 Avion.	6 AGE	7 Design	8 Maint.
Years of Experience	20	4	-	4
% Problems Correctly Solved	.83	.64	.56	.25
Solution Time (Min.)	4.7/2.6	7.3/5.5	7.9/4.3	-
Problem Difficulty (q. 1)	3.2/1.0	3.6/1.6	4.2/0.8	2.9/0.7
Solution Certainty (q. 2)	4.3/0.7	3.5/1.2	4.3/0.5	2.5/0.0
Problem Fidelity (q. 4)	5.3/1.6	6.1/1.3	7.0/0.0	6.0/0.9

*First number = Mean
Second number = Standard Deviation of Mean

Appendix B (continued)

Data Category	Participants			
Specialty (continued)	5 Avion.	6 AGE	7 Design	8 Maint.
HR Data Utility (q. 5)	3.5/0.6	3.4/1.3	3.8/0.3	4.0/2.1
Own Data Utility (q. 7)	6.3/0.7	5.5/1.1	-	2.5/2.1
Own Data Accessibility (q. 8)	6.5/0.6	5.5/1.1	-	4.0/2.1
(A) Hdbk Utility	6.2	2.5	-	4.0
(B) Hdbk Influence	4.7	2.5	3.2	5.5
(C) Use of HR Data	6.4	5.5	7.0	2.5
(D) HR Importance	4.3	4.0	3.7	-
Specialty	9 HF	10 HF	11 HF	12 Crew
Years of Experience	15	10	35	6
% Problems Correctly Solved	.50	.71	.46	.54
Solution Time (Min.)	3.5/1.0	6.2/3.1	5.3/3.0	6.2/2.4
Problem Difficulty (q. 1)	3.5/1.0	4.0/1.6	3.3/1.6	4.6/1.8
Solution Certainty (q. 2)	3.4/0.8	4.2/1.0	3.1/1.3	5.7/1.9
Problem Fidelity (q. 4)	5.2/0.7	4.7/0.8	7.0/0.0	5.7/1.1
HR Data Utility (q. 5)	3.7/1.3	3.2/1.3	1.8/0.6	4.0/1.3
Own Data Utility (q. 7)	4.3/2.2	4.2/2.0	5.5/0.3	4.2/1.1
Own Data Accessibility (q. 8)	5.5/1.1	5.8/0.6	5.7/0.5	4.7/1.3
(A) Hdbk Utility	5.5	2.5	7.0	7.0
(B) Hdbk Influence	5.5	2.5	1.7	4.0
(C) Use of HR Data	4.0	2.5	2.0	5.5
(D) HR Importance	4.0	4.0	4.0	6.2

Appendix B (continued)

Data Category	Participants			
Specialty	13 Design	14 Crew	15 HF	16 Maint.
Years of Experience	10	21	18	18
% Problems Correctly Solved	.67	.46	.75	.71
Solution Time (Min.)	6.9/3.5	6.3/5.3	6.7/3.3	4.6/2.5
Problem Difficulty (q. 1)	4.5/1.6	3.5/1.2	4.2/1.2	4.1/0.6
Solution Certainty (q. 2)	5.5/1.8	4.0/1.1	4.8/1.4	3.5/0.5
Problem Fidelity (q. 4)	6.5/0.8	7.0/0.0	5.2/0.8	5.8/1.1
HR Data Utility (q. 5)	4.7/1.8	3.0/0.8	3.5/1.6	4.5/1.3
Own Data Utility (q. 7)	3.3/1.7	4.0/0.9	4.5/1.9	3.9/2.2
Own Data Accessibility (q. 8)	5.5/0.0	5.5/0.0	5.6/0.5	3.3/0.7
(A) Hdbk Utility	5.5	5.5	2.5	5.5
(B) Hdbk Influence	4.0	4.0	4.0	5.4
(C) Use of HR Data	4.0	4.0	2.6	3.3
(D) HR Importance	4.7	5.5	2.5	3.7
Specialty	17 Train.	18 Ops.An.	19 Design	20 Design
Years of Experience	23	14	25	35
% Problems Correctly Solved	.75	.82	.54	.75
Solution Time (Min.)	4.4/1.8	6.2/2.6	7.2/2.6	8.5/4.0
Problem Difficulty (q. 1)	3.9/0.9	2.7/2.0	3.4/1.4	3.6/1.7
Solution Certainty (q. 2)	4.1/1.0	3.6/1.7	2.9/1.2	3.2/1.1
Problem Fidelity (q. 4)	4.8/1.3	4.0/0.0	6.8/0.3	4.2/0.6
HR Data Utility (q. 5)	4.5/1.1	3.0/1.5	1.9/0.6	4.2/0.6
Own Data Utility (q. 7)	3.4/0.8	5.0/2.3	4.5/1.9	2.7/0.6

Appendix B (continued)

Data Category	Participants			
Specialty (continued)	17 Train.	18 Ops.An.	19 Design	20 Design
Own Data Accessibility (q. 8)	4.3/0.4	5.0/2.0	6.0/0.5	2.5/0.0
(A) Hdbk Utility	6.2	4.0	4.6	5.5
(B) Hdbk Influence	5.5	2.5	2.5	5.5
(C) Use of HR Data	3.5	4.0	6.6	4.0
(D) HR Importance	5.5	4.7	4.3	4.0
Specialty	21 HF	22 AGE	23 REL	24 Maint.
Years of Experience	9	26	15	10
% Problems Correctly Solved	.58	.46	.75	.75
Solution Time (Min.)	2.6/1.4	3.1/2.1	2.7/1.3	5.4/2.5
Problem Difficulty (q. 1)	3.9/1.6	3.4/1.6	2.4/1.0	2.9/0.9
Solution Certainty (q. 2)	4.7/1.1	4.0/1.6	3.8/2.0	3.8/1.5
Problem Fidelity (q. 4)	6.5/0.8	4.7/1.4	4.3/1.1	2.9/0.8
HR Data Utility (q. 5)	4.2/0.6	5.0/2.3	3.0/1.2	4.6/1.1
Own Data Utility (q. 7)	5.0/0.8	4.2/1.5	4.8/1.5	4.3/0.7
Own Data Accessibility (q. 8)	4.7/0.8	4.7/1.8	5.4/1.0	5.2/0.7
(A) Hdbk Utility	7.0	5.1	2.5	-
(B) Hdbk Influence	4.0	5.4	4.8	-
(C) Use of HR Data	4.0	4.0	4.0	-
(D) HR Importance	-	5.5	4.1	-
Specialty	25 Maint.	26 Design	27 Design	28 Misc.
Years of Experience	1	25	12	5
% Problems Correctly Solved	.64	.91	.62	.71

Appendix B (continued)

Data Category	Participants			
Specialty (continued)	25 Maint.	26 Design	27 Design	28 Misc.
Solution Time (Min.)	4.7/2.8	5.4/4.2	6.7/4.1	8.2/4.6
Problem Difficulty (q. 1)	3.7/0.7	1.9/0.1	3.0/1.8	3.5/1.3
Solution Certainty (q. 2)	3.8/0.9	3.8/2.0	3.4/2.4	4.9/1.6
Problem Fidelity (q. 4)	4.4/0.9	7.0/0.0	6.5/1.2	5.9/0.6
HR Data Utility (q. 5)	3.2/0.5	4.5/1.2	2.5/0.0	5.7/2.0
Own Data Utility (q. 7)	4.4/1.2	3.5/1.8	-	7.0/0.0
Own Data Accessibility (q. 8)	5.0/0.7	3.7/1.1	5.5/0.0	6.5/0.7
(A) Hdbk Utility	3.5	7.0	5.5	6.5
(B) Hdbk Influence	4.5	7.0	4.0	3.3
(C) Use of HR Data	7.0	7.0	5.5	5.5
(D) HR Importance	3.2	4.7	4.0	3.4
Specialty	29 Misc.	30 Misc.	31 Train.	32 AGE
Years of Experience	1	11	32	18
% Problems Correctly Solved	.83	.79	.79	.92
Solution Time (Min.)	6.1/3.2	9.1/5.0	5.3/2.9	6.2/3.8
Problem Difficulty (q. 1)	2.7/1.7	3.5/2.0	1.5/1.0	3.6/1.0
Solution Certainty (q. 2)	3.2/1.4	3.1/1.7	2.3/1.2	4.2/2.0
Problem Fidelity (q. 4)	7.0/0.0	4.7/1.1	5.7/2.0	7.0/0.0
HR Data Utility (q. 5)	5.0/1.8	2.3/0.4	2.5/2.1	2.5/0.0
Own Data Utility (q. 7)	6.2/0.8	5.7/0.4	6.0/0.9	6.4/1.3
Own Data Accessibility (q. 8)	7.0/0.0	5.9/0.6	5.0/1.7	6.2/1.3
(A) Hdbk Utility	6.3	3.1	1.0	5.5
(B) Hdbk Influence	2.5	3.2	2.5	5.5

Appendix B (continued)

Data Category	Participants			
Specialty (continued)	29 Misc.	30 Misc.	31 Train.	32 AGE
(C) Use of HR Data	4.0	2.5	2.5	7.0
(D) HR Importance	4.0	4.0	3.2	4.0
Specialty	33 AGE	34 Design	35 Design	36 Avion.
Years of Experience	16	25	8	14
% Problems Correctly Solved	.82	.60	.87	.75
Solution Time (Min.)	6.2/2.7	5.5/2.7	4.7/1.7	3.7/2.2
Problem Difficulty (q. 1)	4.8/1.4	2.3/0.8	3.0/1.5	3.0/1.0
Solution Certainty (q. 2)	3.9/1.4	2.8/1.3	3.4/2.0	3.2/1.6
Problem Fidelity (q. 4)	5.5/1.0	6.2/1.5	6.5/0.8	5.7/1.1
HR Data Utility (q. 5)	4.5/0.9	2.5/0.0	2.5/0.0	4.0/1.6
Own Data Utility (q. 7)	5.1/1.5	5.5/2.1	5.0/1.2	5.5/1.3
Own Data Accessibility (q. 8)	5.8/1.1	6.5/0.9	5.5/0.0	5.2/1.1
(A) Hdbk Utility	4.0	5.5	4.7	4.0
(B) Hdbk Influence	4.9	2.5	2.5	4.0
(C) Use of HR Data	2.5	7.0	4.7	4.0
(D) HR Importance	4.3	4.0	4.0	5.5

APPENDIX C

PARTICIPANT RESPONSES BY PROBLEM

Data Category	Problems			
	1	2	3	4
% Problems Correctly Solved	*.61/.32	.65/.35	.79/.30	.68/.32
Solution Time (Min.)	5.3/2.5	5.6/2.9	6.4/4.9	8.2/4.1
Problem Difficulty (q. 1)	2.9/1.3	2.9/1.5	3.7/1.6	4.8/1.2
Solution Certainty (q. 2)		3.4/1.3		
Problem Fidelity (q. 4)		5.2/1.6		
HR Data Utility (q. 5)		3.3/1.3		
Own Data Utility (q. 7)		4.2/1.8		
Own Data Accessibility (q. 8)		5.2/1.1		
	5	6	7	8
% Problems Correctly Solved	.41/.32	.79/.28	.62/.46	.94/.20
Solution Time (Min.)	7.8/3.6	5.3/2.8	4.3/9.5	2.8/1.8
Problem Difficulty (q. 1)	3.3/1.4	2.8/1.4	5.0/1.6	2.8/1.1
Solution Certainty (q. 2)	**5.4/1.5 3.0/1.0	3.3/1.5		
Problem Fidelity (q. 4)	6.1/1.2	5.9/1.3		
HR Data Utility (q. 5)	3.1/1.5	3.7/1.5		
Own Data Utility (q. 7)	5.6/1.3	4.7/1.7		
Own Data Accessibility (q. 8)	5.4/1.7	5.4/1.3		

*First Number = Mean of 36 participants
Second Number = Standard Deviation of Mean

**Data from problem 5 (above, without handbook, below, with handbook).

Appendix C (continued)

Data Category	Problems			
	9	10	11	12
% Problems Correctly Solved	.56/.48	.70/.37	.92/.25	.90/.17
Solution Time (Min.)	2.1/6.3	3.5/1.9	4.3/2.7	4.3/2.0
Problem Difficulty (q. 1)	3.8/1.4	2.3/0.9	3.5/1.5	3.0/1.0
Solution Certainty (q. 2)	**5.3/1.4 4.1/1.4	2.7/1.1		3.4/0.9
Problem Fidelity (q. 4)	5.6/1.7	5.4/1.5		5.5/1.3
HR Data Utility (q. 5)	4.2/1.6	3.6/1.4		3.4/1.6
Own Data Utility (q. 7)	4.4/1.4	4.9/1.5		4.6/1.3
Own Data Accessibility (q. 8)	5.2/1.2	5.2/1.3		5.2/1.3

**Data from problem 9 (above, without handbook, below, with handbook).

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